Report ASD/XR-TR-75-4

ANALYTICAL METHODOLOGY FOR EVALUATION OF PAYOFFS FOR INFRARED COUNTERMEASURES AND SUPPRESSION (EPICS)

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Deputy for Development Planning

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An analytical methodology for assessing the impact of infrared suppression techniques on aircraft survivability in an IR missile threat environment has been developed. The methodology, designated as EPICS (Evaluation of Payoffs for Infrared Countermeasures and Suppression) consists of two digital computer programs: (1) ASDIR II, and (2) M/T/CM. The ASDIR II program generates aircraft IR signatures. The M/T/CM, a five-degrees-of-freedom program, computes the probability of aircraft

20. Abstract (Continued)

survival based on a simulated missile-target engagement, including the dynamics and principal characteristics of the aircraft and the missile. The program can also simulate the deployment of decoys such as flares or pyrophorics.

The utility of the program lies in that it can provide guidelines during aircraft configuration studies, assess effects of design changes on aircraft survivability, and permits tradeoff studies to be made between various CMs such as suppression, shielding and flare deployment.

The programs are operational on the CDC 6600 digital computer at Wright-Patterson Air Force Base, Ohio.

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INTRODUCTION

This document constitutes the final report on Analytical Methodology for Evaluation of Payoffs for Infrared Countermeasures and Suppression (EPICS), Contract No. F33615-75-C-4076. The prime objective of this study was to develop a methodology or analytical tool for rapidly and efficiently assessing the impact of infrared suppression techniques on aircraft survivability. Specifically, the intended purpose of the methodology is to provide a capability to analytically predict the effectiveness of aircraft design changes (primarily those related to infrared signature) on the probability of aircraft survival in a specified infrared threat environment.

The development of an analytical tool that meets the above objectives was achieved. This tool consists of two complementary digital computer programs: (1) an infrared target signature model (ASDIR II) and (2) a missile/target/countermeasures (M/T/CM)* model. A third program SPKINT (a subroutine) provides the interface between the two models. All three programs are fully operational on the CDC 6600 computer system. This total methodology system is designated as EPICS.

The first program, ASDIR II, was primarily developed by the Air Force. Hughes modified it and made it operational.** It is documented under a separate cover.*** The inputs to ASDIR II are engine specification data (gas dynamics or measured plume data to determine the engine exhaust plume radiation) and engine hot metal parts in terms of temperature and radiating

*The baseline for the M/T/CM program was developed by Hughes under "IRCM Simulation Study", Contract No. F33615-C-74-1680 for AFAL.

**This task constituted a deviation from the Statement of Work. Originally, a Hughes'-developed target signature program, IRSIG, was to be used. However, on Program Monitors instructions, ASDIR II was used instead.

***Stone, Charles W., Capt., USAF and Tate, Stanley, ASDIR II (Vol. I, II, and III), Deputy for Development Planning, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, No. ASD/XR-TR-75-1, January 1975.

area as a function of aspect. Similarly, the contribution to the total IR signature due to skin aerodynamic heating is an input in terms of temperature and radiating area for as many as twenty skin surfaces. Finally, the viewing geometry — target and observer altitudes, aspect angle, and slant range is an input to the ASDIR II program.

The outputs of this code are in the form of polar data for the source spectral radiant intensity, J_λ, integrated over the missile response band and the apparent spectral radiant intensity, $J_\lambda \tau_\lambda$, also integrated over the missile band, but at the point of a remote observer. These data then serve as input to the M/T/CM program.

The second major element of EPICS is the M/T/CM. This program is described in detail in this report. The program is a generic five-degrees-of-freedom dynamic simulation of the total missile/target encounter in a countermeasures environment. The prime countermeasures technique that can be evaluated using this program are IR signature reduction through suppression or shielding, and active decoys such as flares or pyrophorics. The output of the program is a probability of target survival (P_S) under a varied set of launch conditions and for various IR missile threats. The P_S is defined by

$$P_S = \frac{\text{number of misses}}{\text{total number of launch cases}}$$

As indicated in a preceding footnote, the baseline subroutines for the M/T /CM program were developed by Hughes under an earlier Air Force study program, however, in the present study contract this baseline program was considerably expanded and improved. In addition, the program was modified to accept inputs from the ASDIR II program with the aid of a subroutine called SPKINT. The total program was compiled on the CDC 6600 computer system (it was originally written for the SIGMA 5 Computer). The major changes to M/T/CM include:

Modularization of the program

Addition of flare control options (function of range and time-to-go)

Addition of superelevation angle subroutine for ground-to-air missiles

Addition of launch mode selection option in azimuth and elevation

Reduction of program execution time

Sample runs using all three programs were also made; see Section 10.

In this program, a specific target is represented by its physical characteristics, its dynamic parameters, and its infrared signature. The physical characteristics include the size of the aircraft, its wing span and the engine location. The dynamic parameters include initial velocity, accelerations, and maneuvers. The infrared target signature is represented by the effective apparent radiant intensity, $J\tau_{\Delta\lambda}$, as a function of range and aspect angle, and is calculated by ASDIR II. Interpolation on range and aspect angle between $(J\tau)_{\Delta\lambda}$ data points provide the appropriate values during the simulated flight which in turn are used to calculate the effective irradiance at the missile seeker.

Threat missiles are represented by a number of parameters divided into six categories: seeker, signal processing, guidance, aerodynamics, propulsion, and physical characteristics. Currently, 12 missiles, 25 aircraft, and 4 flare types have been defined and are part of the simulation file.

The M/T/CM program has been validated by comparing simulated engagements of captive missiles being decoyed by flares, with flight test results (using same flight conditions and the same missiles) conducted by the Naval Weapons Center, China Lake, California.

As mentioned above, the interface between the ASDIR II signature program and the M/T/CM program is provided by an auxiliary spectral integration subroutine, called SPKINT. This routine integrates the apparent spectral radiant intensity values, $J_\lambda \tau_\lambda$, over any specified spectral interval to obtain effective radiant intensity $(J\tau)_{\Delta\lambda}$. In general, the integration is performed for spectral intervals corresponding to the spectral bandpasses of the 12 missiles on file. The SPKINT subroutine is described in Section 9.

In summary, the EPICS methodology provides a tool to assess the impact that aircraft design has on the aircraft survivability in an infrared missile threat environment, evaluating design changes and conducting tradeoff studies during preliminary design and determining aircraft survivability in a flare countermeasures environment.

Figure 1 shows a flow diagram for the simulation program executive operation that calls all subroutines. The program is broken into eight major areas with each area being subsequently discussed in Sections 1 through 8 of this report.

Section 1 deals with the creation of files on which the necessary constants for the missile, target, and flare are stored. Long lists of input data can be eliminated, by creating files for each missile, target, and flare to be evaluated and the required constants can be specified by simply referring to a file name.

In Section 2, the launch geometry variables, the flare deployment strategy, the aircraft maneuver option, and all other program options are set. In this section, all program variables are initialized.

Section 3 of the program updates the position, velocity, and acceleration of the missile, target, and flare(s) with respect to inertial coordinates.

In Section 4, relative ranges, range rates, angles, and angular rates are determined between the missile and the target as well as the missile and flare(s).

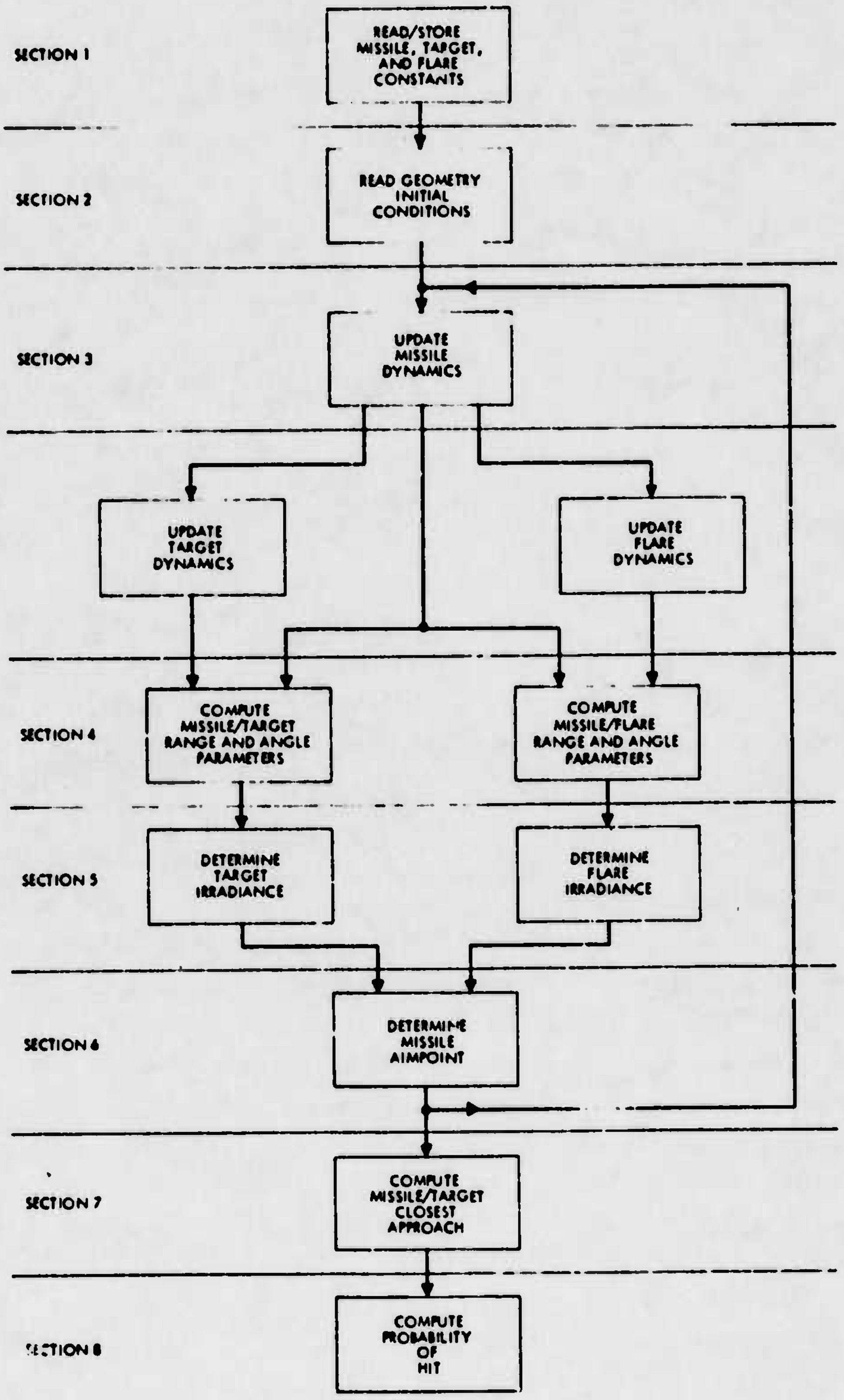
The irradiance at the missile dome from the target and the flare(s) is computed in Section 5.

In Section 6, the aimpoint location is determined based on the irradiance levels of the sources in its field of view (FOV) and the type of signal processing in the missile. This aimpoint location is then fed back into the missile dynamics (Section 3) through missile guidance.

When the simulation program goes into an abort mode, the point of closest approach of the missile to the target is determined. The details are given in Section 7.

Section 8 describes how the probability of hit is determined based on the closest approach distance, aircraft dimensions, type, and lethality of the missile warhead.

The geometry for the missile and target encounter is shown in Figure 2. This simulation is based on a two-plane geometry, because a missile essentially processes its target position and rate information and provides guidance commands in two separate planes -- horizontal and vertical. Coupling between the two planes is accomplished by the range and velocity variables.


SECTION 1
READ/STORE MISSILE, TARGET, AND FLARE CONSTANTS
SECTION 2
READ GEOMETRY INITIAL CONDITIONS
SECTION 3
UPDATE MISSILE DYNAMICS
UPDATE TARGET DYNAMICS
UPDATE FLARE DYNAMICS
SECTION 4
COMPUTE MISSILE/TARGET RANGE AND ANGLE PARAMETERS
COMPUTE MISSILE/FLARE RANGE AND ANGLE PARAMETERS
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DETERMINE TARGET IRRADIANCE
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SECTION 7
COMPUTE MISSILE/TARGET CLOSEST APPROACH
SECTION 8
COMPUTE PROBABILITY OF HIT

Figure 1. Simulation program executive operation flow diagram

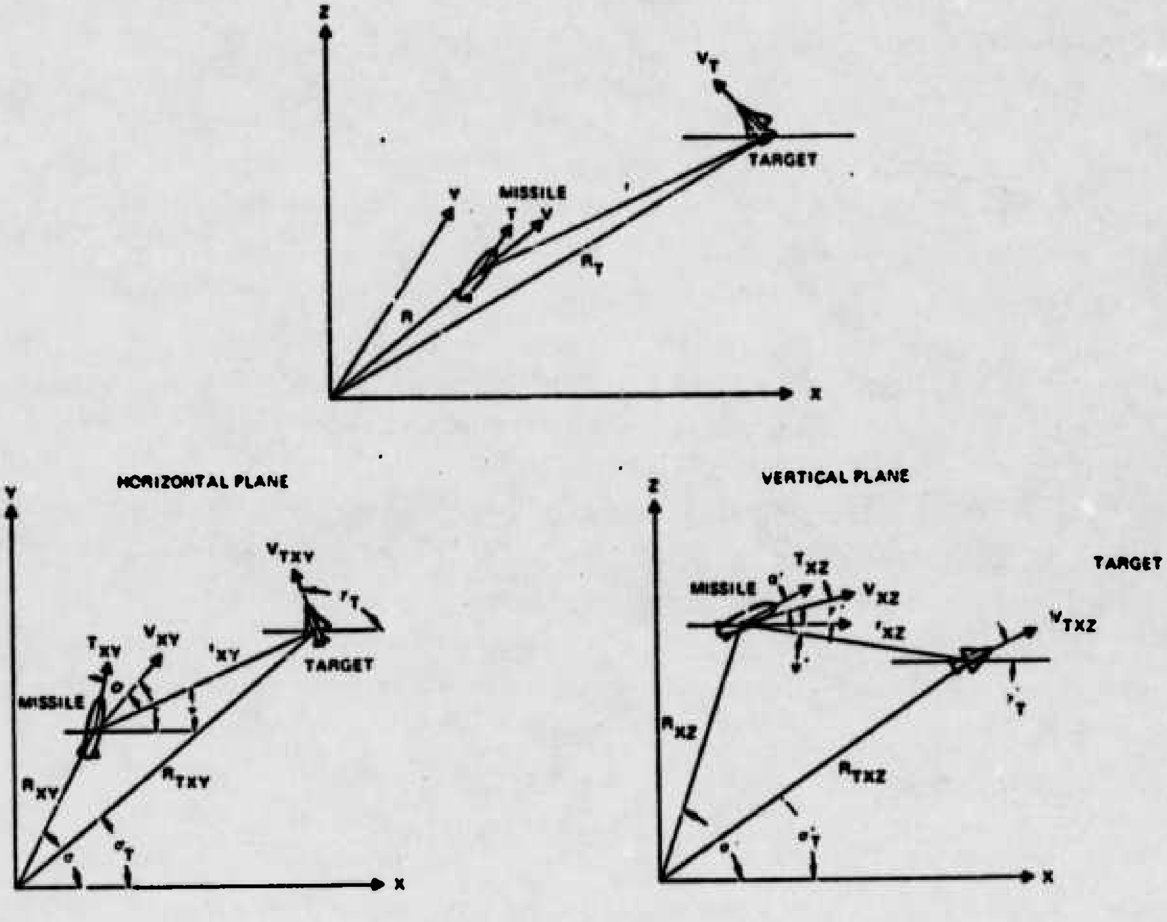

Figure 2. Missile and target geometry

The coordinate system in which missile, target, and flare positions are calculated is shown in Figure 2. This system has as its crigin a point on the ground directly below the launch point of the missile. The Z axis is parallel to gravity and positive up. Therefore the initial position of the missile is given by (O, O, Z_A), where Z_A is the launch altitude. The X axis is perpendicular to gravity and oriented such that the initial position of the target is in the X-Z plane. The Y-axis completes the orthognal, right-handed coor.dinate system. The initial position of the target is given by (X_T, O, Z_T) with X_T being the horizontal range between the missile and target at launch, and Z_T being the target altitude. From this definition, the line-of-sight (LOS) is in the X-Z plane from the missile to target at launch. The target aspect relative to the missile is set by the target velocity vector.

The state vectors listed in Table 1 represent the X-, Y-, and Z-components of position, velocity, and acceleration of the missile and target. The state variables are divided into two sets: one set for the horizontal plane and one set for the vertical plane.

Figure 3 shows the geometry that exists between the missile and an arbitrary flare (the K^{th} flare). Again, as in the case of the missile and target geometry, the problem is divided into two planes, horizontal and vertical.

The state vector for the K^{th} flare is listed in Table 2. As in the case of the missile and target state vector system, the first five components represent the position, velocity, and acceleration of the missile; while the next four components represent the position and velocity of the K^{th} flare. It is assumed that the flare has no thrusting device, and therefore no thrust acceleration terms are possible. As before, the state variables are divided into the sets -- one for each plane. The executive routine listing for the simulation program is presented in Table 3. All subroutines in the simulation program are called by this routine.

Table 1. Missile and target state variable definitions

Horizontal Plane	Vertical Plane
X(1) = X - Position of Missile	XP(1) = X - Position of Missile
X(2) = X - Velocity of Missile	XP(2) = X - Velocity of Missile
X(3) = Y - Position of Missile	XP(3) = Z - Position of Missile
X(4) = Y - Velocity of Missile	XP(4) = Z - Velocity of Missile
X(5) = Normal Acceleration (XY) of Missile	XP(5) = Normal Acceleration (XZ) of Missile
X(6) = X - Position of Target	XP(6) = X - Position of Target
X(7) = X - Velocity of Target	XP(7) = X - Velocity of Target
X(8) = Y - Position of Target	XP(8) = Z - Position of Target
X(9) = Y - Velocity of Target	XP(9) = Z - Velocity of Target
X(10) = Normal Acceleration (XY) of Target	XP(10) = Normal Acceleration (XZ) of Target

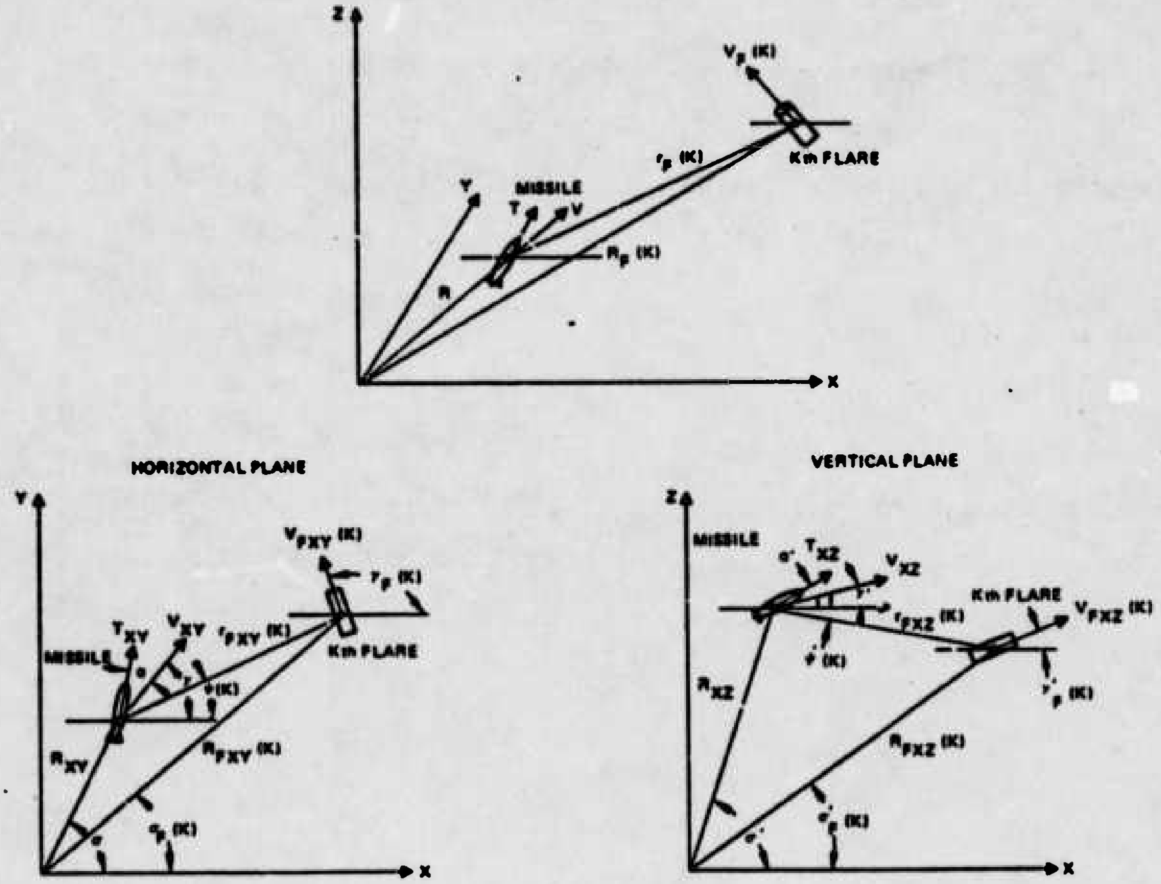

Figure 3. Missile and Kth flare geometry

Table 2. Missile and Kth flare state variable definitions

Horizontal Plane	Vertical Plane
XF(1, K) = X - Position of Missile	XFP(1, K) = X - Position of Missile
XF(2, K) = X - Velocity of Missile	XFP(2, K) = X - Velocity of Missile
XF(3, K) = Y - Position of Missile	XFP(3, K) = Z - Position of Missile
XF(4, K) = Y - Velocity of Missile	XFP(4, K) = Z - Velocity of Missile
XF(5, K) = Normal Acceleration (XY) of Missile	XFP(5, K) = Normal Acceleration (XZ) of Missile
XF(6, K) = X - Position of Kth Flare	XFP(6, K) = X - Position of Kth Flare
XF(7, K) = X - Velocity of Kth Flare	XFP(7, K) = X - Velocity of Kth Flare
XF(8, K) = Y - Position of Kth Flare	XFP(8, K) = Z - Position of Kth Flare
XF(9, K) = Y - Velocity of Kth Flare	XFP(9, K) = Z - Velocity of Kth Flare

Table 3. Simulation program executive routine

```
PROGRAM EPICS      74/74    OPT=1                              FTN 4.2+P380        05/31/75   13.30.19.

                                                                                     EPICS      2
      PROGRAM EPICS(INPUT,OUTPUT,TAPE12,TAPE7,TAPE9,TAPE13,TAPE11,TAPE14 EPICS      3
     1              ,TAPE5=INPUT,TAPE6=OUTPUT)                          EPICS      4
      REAL JF,JIN                                                        EPICS      5
      DIMENSION HF(20),NTS(2),TF(20),RTLF(9,20),REL(12),IJDIR(8)         EPICS      6
      DIMENSION SF(20),WF(20),JF(20),VF(20)                              EPICS      7
      DIMENSION RF(20),RDF(20),TTGF(20),XFD(10,20)                       EPICS      8
      COMMON /BLK1/ST(10),TL(10),SIN(10),HD(10),VMC(8),CDD(8),CNT(8),GMA EPICS      9
     +(10),ALPH(10,8),LL,SA,ALIM,FOV,AS,TMAX,D1,TS,TR,A6,WM,TGU,RMK,GKO, EPICS     10
     +IRNOM,MISTYPE(2),BLURC,NMIN,DDD(9)                                 EPICS     11
      COMMON /BLK2/FMS,AM,VMAX,XR,XM,TT,ZD,IAD,TOTALT,VELT,PANG(30),RINT EPICS     12
     +(30)                                                               EPICS     13
      COMMON /BLK3/IFTYPE(2),MK,DF,VL,TBURN,WFO,CDF,FISANG(5),REFI,NG,VF EPICS     14
     +LARE,TTN(103),JIN(103)                                             EPICS     15
      COMMON /BLK4/RNG(19),TAUT(19),TAUP(19)                             EPICS     16
      COMMON SSW1,SSW2,SSW3,SSW4,DIES,IDSPLAY,MSTL,IFF                   EPICS     17
      COMMON PI,RHO,M1,VP,DF,T,VOLDV,TIN,V                               EPICS     18
      COMMON DELV,AM,RET,SFP,TUP,TLOW                                    EPICS     19
      COMMON NFLARE,IFDIR(20),NLD,ADISP,AV,THACM,G,S                    EPICS     20
      COMMON IST(20,3)                                                   EPICS     21
      COMMON NN(20),LP,N                                                 EPICS     22
      COMMON TF(20),FSF(20),ATFR4(20),SINN,SIPN,SIDN,SIDPN,T,SI,SIP      EPICS     23
      COMMON VXF(20),VYF(20),VZF(20),Z(10),ZP(10),X(10),XP(10)           EPICS     24
      COMMON TF(3,20),TFD(3,20),XF(10,20),XFD(10,20),VT                  EPICS     25
      COMMON X20,X40,XP40,XT0,X30,XP30,THRUST                            EPICS     26
      COMMON ALPHA,ALPHAP,TX,TY,TZ,CX,CY,CZ,AX,AY,AZ                     MAR19      1
      NAMELIST/PARAM/SSW1,SSW2,IRNOM,WFO,SA,A,TR,FOV,AS,TMAX,            MAR19      2
     +GKO,D1,TS,TR,A6,W,IOPT,NG,TM,X,XP,L,CDF,RINT,PANG,                 MAR19      3
     +GMA,NMIN,VMC,CDD,CNT,TBURN,TGU,IRNO,XSAIN,NFLARE,G,                MAR19      4
     +RET,AM,DIES,TLOW,TUP,AV,VDISP,NLD,IFD,TIN,TPLOT,REFI,              MAR19      5
     +IDSPLAY,ST,TDPLOT,RR,RDF,TTGF,SUPELD,T4THRD,LMSF,                  MAR19      6
     +LMSA,CLD,TL,SIN,HD,HTC,RUN,ALPHA,SSW2,SSW4,RNG,                    MAR19      7
     +TOTALT,VELT,XP,VM,VS,PS                                            EPICS     37
      DATA(IJDIR(J),J=1,8)/90.,270.,0.,180.,45.,135.,225.,315./          MAR20      1
      REWIND 7                                                           MAR20      2
      REWIND 11                                                          MAR20      3
      REWIND 12                                                          MAR20      4
      REWIND 14                                                          MAR19      8
      CALL FLTCNST(RUN,IDPLOT,TOPT)                                      EPICS     40
      READ(5,17) NFLARE                                                  MAR20      5
      IF(NFLARE.EQ.0) GO TO 5                                            MAR19      9
   17 FORMAT(I1)                                                         EPICS     43
      READ(5,16) (IFDIR(J),J=1,NFLARE)                                   MAR19     10
   16 FORMAT(20I1)                                                       EPICS     45
    5 READ(5,15) (MTS(J),J=1,2)                                          EPICS     46
   15 FORMAT(2A6)                                                        MAR19     11
      CALL MSLCNST(MTS,WTP,W,G,L)                                        MAR19     12
      CALL TGTCNST(IRNOM,TR)                                             EPICS     49
      CALL RVSTAU(TOTALT,IRNOM)                                          MAR19     13
   11 READ(5,PARAM)                                                      EPICS     51
      IF(IFND.NE.0) GO TO 2                                              EPICS     52
      IF(NIP.GT.0) GO TO 3                                               EPICS     53
      RUN=RUN+1.                                                         EPICS     54
      CALL INITIAL(M1,T3,MK,DF,VELT,TOTALT,IAD,IRNOM,WFO,CDF,IFTYPE,MIST EPICS     55
     +YPE,NFLARE,NS,TL,TBURN,VM,VMAX,IJDIR,T,RUN,AM,M)                   EPICS     56
      CALL LEAD(SL,X,XP,RET,AM,VL,DELV,G,TS,CLD,ALPHA,LMSF,LMSA,SUPELD,T EPICS     57
     +4THRD,PI)                                                          EPICS     58
      CALL HITPAGE(N(2),RUN,MISTYPE,SSW4,L)
```

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(Table 3, continued)

```
PROGRAM EPICS      74/74   OPT=1                        FTN 4.6+478       05/01/79  13.[illegible].19.

           GO TO 6                                                              EPICS      59
         5 T=T+DELT                                                             EPICS      60
           IF(T.LT.TMAX) GO TO 15                                               EPICS      61
           WRITE(6,14)                                                          EPICS      62
        14 FORMAT(/,2X,24HMISSILE LIFESPAN EXCEEDED,/)                          EPICS      63
           GO TO 17                                                             EPICS      64
        15 N1=M1+1                                                              EPICS      65
           CALL GRNDFN (SIO,SIOP,SI,SIP,SION,SIOPN,SIN,SIPN,VLTM,ALPHA,ALPH     MAR19      14
          +AP,Z(3),ZP(3),DELT,LP,FOV,SS,TAU,T)                                  EPICS      67
           IF(LP.EQ.2) GO TO 18                                                 EPICS      68
           CALL THRUST(TL,SIN,WO,Z,ZP,ALPHA,ALPHAP,THRUST,W,T,DELT,TX,TY,TZ,G   EPICS      69
          +)                                                                    EPICS      70
           CALL FORMAT(X(5),XP(5),DT,S,W,DL,VMM,RHO,VMS,CNA,ALPH,AMACH,ALPHA    EPICS      71
          +,A,RHOP,AS,SCO,CNT,SIN,SIPN,SION,SIOPN,THRUST,Z(3),ZP(3),DELT,TS,R   EPICS      72
          +IAS,AX,AY,AZ,TX,T,DL)                                                EPICS      73
           CALL CHRDR(FMACH,VMM,COD,RHO,DI,D,DL,Z,ZP,ALPHA,ALPHAP,VMS,W,CX,CT   EPICS      74
          +,CP)                                                                 EPICS      75
           X2P=TX+AX*CX                                                         EPICS      76
           X4P=TY+AY*CT                                                         EPICS      77
           X6P=TZ+AZ*CF-G                                                       EPICS      78
           X(2)=X(2)+X2P*DELT                                                   EPICS      79
           X(4)=X(4)+X4P*DELT                                                   EPICS      80
           XP(6)=XP(6)+XP6*DELT                                                 EPICS      81
           X(1)=X(1)+X(2)*DELT                                                  EPICS      82
           X(3)=X(3)+X(4)*DELT                                                  EPICS      83
           XP(5)=XP(5)+XP(6)*DELT                                               EPICS      84
           IF(XP(3).GT.0.) GO TO 20                                             EPICS      85
           WRITE(6,21) T                                                        EPICS      86
        21 FORMAT(2X,27HMISSILE HIT GROUND AT TIME ,F9.6)                       EPICS      87
           GO TO 17                                                             EPICS      88
        20 IF(NPLANE.EQ.1) GO TO 9                                              EPICS      89
           IF(IPOLDY.EQ.1) GO TO 12                                             EPICS      90
           IF(TO.GE.T) GO TO 9                                                  EPICS      91
        12 CALL FLPATH  (NN,N,TST,T,TF,FTS,FTSP,SSMP,XF,XFO,X,XO,TAJON,VXF,V    MAR19      15
          +YF,VZF,YFO,ZFO,VFZO,PEL,RF,RFF,IPOLDY,N,PI,T)                        EPICS      93
           IF(N.EQ.3) GO TO 9                                                   EPICS      94
           CALL FLPOTN  (T,DELT,TF,TAJON,SF,SFO,DF,WFO,WG,WF,N,RHO,CDF,G,VF,X   MAR19      16
          +,XO,XFO,VF,XFO,NN,NK)                                                EPICS      96
           CALL MFLRTEL(N,XF,YFO,XFO,VF,AF,DELT)                                MAR19      17
           CALL MFLANG(XF,N,ZF,PI)                                              MAR19      18
           CALL MFLANG(VFO,N,YFO,PI)                                            MAR19      19
           CALL FLPIR   (T,TF,DELF,N,VF,WF,RF,IOPT,TTN,JIN,FIBRND,IRNDM,FSF,F   MAR19      20
          +SFI,TAUFN,VTFON,RNS,TAJF)                                            EPICS     101
           N1=N1+1                                                              EPICS     102
           IF(N1.LT.M2) GO TO 8                                                 EPICS     103
         9 CONTINUE                                                             EPICS     104
           DO 7 K=1,M                                                           EPICS     105
           GO TO (17,13,7), MM(K)                                               EPICS     106
        13 IF(XFM(3,K).GT.0.) GO TO 16                                          EPICS     107
           JF(K)=0.                                                             EPICS     108
           MF(K)=0.                                                             EPICS     109
           GO TO 7                                                              EPICS     110
        16 IF(SSMP.EQ.0.) GO TO 7                                               EPICS     111
           ZF1=ZF(1,K)*M1                                                       EPICS     112
           ZF2=ZFP(1,K)*M1                                                      EPICS     113
           ZF3=ZF(2,K)*M1                                                       EPICS     114
           ZF4=ZFP(2,K)*M1                                                      EPICS     115
```

(Table 3, concluded)

```
PROGRAM EPICS      74/74   OPT=1                        FTN 4.2+P380       05/31/79  13.33.19.

          WRITE(6,672) K                                                   EPICS     116
      672 FORMAT(5X,7HNUMBER ,I4,1X,21HPLACE CHARACTERISTICS)              EPICS     117
          WRITE(6,673) XP(5,K),XP(6,K),XP(9,K)                             EPICS     118
          WRITE(6,674) XP(7,K),XP(8,K),XP(9,K)                             EPICS     119
          WRITE(6,675) RELP(1,K),RELP(2,K),RELP(3,K)                       EPICS     120
          WRITE(6,676) RELP(7,K),RELP(8,K),VP(K)                           EPICS     121
      673 FORMAT(2X,4HREL=,F8.2,2X,5HRDIEL=,F8.2,1X,3HVP=,F9.2)            EPICS     122
      674 FORMAT(6X,4HXREL=,F10.2,2X,5HYREL=,F9.2,2X,5HZREL=,F9.2)         EPICS     123
      675 FORMAT(2X,6HVXREL=,F9.6,2X,6HVYREL=,F9.6,2X,6HVZREL=,F9.6)       EPICS     124
      676 FORMAT(6X,3HXP=,F13.7,2X,3HYP=,F16.6,2X,3HZP=,F19.6)             EPICS     125
          WRITE(6,993) SP(K),HP(K)                                         EPICS     126
      993 FORMAT(2X,3HSP=,F12.5,2X,7HHEIGHT=,F12.5)                        EPICS     127
          WRITE(6,692) IP(K),HP(K)                                         EPICS     128
      692 FORMAT(2X,13HINTENSITY =,F12.5,2X,11HRADIANCE =,F12.6)           EPICS     129
          WRITE(6,996) ZP1,ZP2,ZP3,ZP4                                     EPICS     130
      996 FORMAT(2X,7HSIGPI =,F12.5,2X,7HSIGPIT=,E12.5,2X,10HSIGPOTINT =,E12.  EPICS     131
         +6,2X,10HSIGPOTIN2 =,F12.6)                                       EPICS     132
        7 CONTINUE                                                         EPICS     133
        5 CALL TGTPM    (T,TM,DELT,A4,G,FM3,VM,VT,X(5),X(6),XP(6),X(7),X(8),X  MAR20       5
         +P(3),X7),X9),XP9),Z(P))                                          EPICS     134
        6 VM=SQRT(X(2)*X(2)+X(4)*X(4)+XP(6)*XP(6))                         EPICS     135
          CALL MTRVEL  (X,XP,X2D,X6D,XP6D,X7D,X9D,XP9D,T,VMM,VMD,VT,VTD,REL,  MAR20       7
         +L2,TTG,RMISS,MSS1)                                               EPICS     136
          IF(L2.EQ.2) GO TO 10                                             EPICS     137
          CALL MTSTANG    (X,ALPHA,X6D,X7D,X9D,X7D,T,PI)                   MAR20       8
          CALL MTSTANG    (XP,ALPHAP,X6D,XPD,X9D,X7D,ZP,PI)                MAR20       9
          CALL TGTIR    (X(7),X(8),XP(9),VT,REL(1),REL(2),REL(9),REL(10),PI,R  MAR20      10
         +INT,PANG,RAD,TOUT,AI,TINT)                                       EPICS     138
          CALL MSLAMPT (ZP,ZPP,Z,TP,RELP,REL,NT,NL,MP,N,MP,KT,LT,SI,SIP,SID,  MAR20      11
         +SIDP,PE,RADOT,FOV,L2,NSIN,LL,T)                                  EPICS     139
          IF(L2.EQ.2) GO TO 10                                             EPICS     140
          IF(N1.LT.N2) GO TO 9                                             EPICS     141
          N1=0                                                             MAR20      12
          IF(SSW3.NE.0.) GO TO 22                                          EPICS     142
          GO TO 23                                                         EPICS     143
       22 NN1=N-1                                                          MAR19      21
          WRITE(8) DJN,NN1,XP(3),XP(8),(XP(8,NN),NN=1,NN1),X(3),X(8),       MAR19      22
         +(XP(8,NN),NN=1,NN1),X(7),X(6),(XP(6,NN),NN=1,NN1),SI,Z(3),(ZP(1,NN  MAR19      23
         +),NN=1,NN1),STP,ZP(3),(ZP(1,NN),NN=1,NN1),(IGT(NN),NN=1,NN1),     MAR19      24
         +NN=1,2),(JP(NN),NN=1,NN1),(RELP(7,NN),NN=1,NN1),(RELP(8,NN),NN=1,N  MAR19      25
         +N1),NT,REL(10),REL(11),T                                         MAR19      26
       23 IF(T.GT.3.) GO TO 32                                             EPICS     169
          IF(SSW4.GT.0.) GO TO 32                                          EPICS     170
          CALL PAGE2(IAG,VELT,TGTALT,ITYPE,Y,ZP,SI,STP,SID,SIDP,REL,X,XP,XP  EPICS     171
         +D,X6D,XP6D,X7D,X9D,XP9D)                                         EPICS     172
       32 CALL OUTPUT(X,XP,Z,ZP,ALPHA,ALPHAP,Z6,RADOT,SIGM,SIPM,SIDM,SIDPM,X  EPICS     173
         +7D,X6D,XP6D,VT,VMM,FMACH,DEL,RMISS,TTG,THRUST,N,NT,T,SSW2,IX,IY,IZ  EPICS     174
         +,BX,BY,BZ,CX,CY,CZ)                                              EPICS     175
          GO TO (9,1), L2                                                  EPICS     176
        1 IF(NTP.GT.0) GO TO 3                                             EPICS     177
          GO TO 11                                                         EPICS     178
       10 TMISS=RMISS                                                      EPICS     179
          CALL CLOSAPP   (REL,TTG,DELT,RMISS,XP,T,TMAX,XM,YM,ZM,TTGT)       MAR20      13
          CALL PHCOMP(REL,ZIP,ONE,YP,XP,XM,ZS,PH)                          EPICS     181
          CALL FINPAGE(XM,YM,ZM,REL,RMISS,TMISS,TTGT,TTG,PH)               EPICS     182
          IF(SSW6.EQ.0.) GO TO 30                                          EPICS     183
          WRITE(13) RMISS,PH,TMISS,REL(13)                                 EPICS     184
          ENDFILE 13                                                       EPICS     185
       30 IF(SSW5.NE.0.) GO TO 29                                          EPICS     186
          IF(IOPPLOT.EQ.0) GO TO 11                                        EPICS     187
          ENDFILE 9                                                        EPICS     188
          WRITE(8,28) RMISS,T,PH                                           EPICS     189
       28 FORMAT(3E12.6)                                                   EPICS     190
       29 ENDFILE 8                                                        EPICS     191
          GO TO 11                                                         EPICS     192
        2 IF(SSW6.EQ.0.) GO TO 31                                          EPICS     193
          ENDFILE 13                                                       EPICS     194
          REWIND 13                                                        EPICS     195
       31 STOP                                                             EPICS     196
          END                                                              EPICS     197
```

1. FILE CREATION

Information used to create missile, target and flare file data has been collected at Hughes over a long period. Pertinent sources are listed in the references at the end of this section.

MISSILE FILE

The missile information is divided into seven categories: seeker, signal processing, guidance unit, aerodynamics, motor, physical characteristics, and other characteristics. Table 1-1 is the missile file subroutine. See Table 1-2 for sample file data.

Seeker

The seeker is defined as:

1. Seeker look angle (deg), variable name SA. This is the angle about the longitudinal axis of the missile in any plane that the gyro is free to move.
2. Max gyro rate (deg/sec.), variable name WLIM.
3. FOV (deg), variable name FOV.
4. Gyro time lag (sec.), variable name TGU.

Signal Processing

The signal processing includes:

1. The detector bandwidth of the missile, variable name IBNDM. The bandwidth value is currently deleted from the missile page printout.
2. Aimpoint type is selected on the basis of geometric centroid, irradiance centroid, and maximum irradiance.

The present available missiles are divided into two categories: the con-scan missile which is a maximum irradiance tracker, and the spin-scan missile which is an irradiance centroid tracker. Geometric centroid does not apply to the current systems

Table 1-1. Missile file subroutine

```
SUBROUTINE MSLCNST    74/74    OPT=1                         FTN 4.2+P380        05/01/75  13.30.35.

              SUBROUTINE MSLCNST(MTS,NTC,M.P,G.)                                  MAR19       29
              DIMENSION MTS(2)                                                    MSLCONST     3
              COMMON /BLK1/ST(10),TL(10),SIM(10),MD(10),VMC(8),CDD(8),CNS(8),CNA  MSLCONST     4
             *(10),ALPH(10,8),LL,SA,WLIM,FOV,AS,TMAX,D1,TS,TR,AS,WN,TGU,RMK,CKO,  MSLCONST     5
             *IONOM,MISTYPE(2),BLURC,MMIN,DD(9)                                   MSLCONST     6
              NL3=3                                                               MSLCONST     7
              GL=0.                                                               MSLCONST     8
              NTS=0                                                               MSLCONST     9
              NPTS=10                                                             MSLCONST    10
              RAD=3.141592/180.                                                   MSLCONST    11
            6 READ(7)  (ST(LA),LA=1,NPTS)                                         MSLCONST    12
              READ(7)  (TL(LA),LA=1,NPTS)                                         MSLCONST    13
              READ(7)  (SIM(LA),LA=1,NPTS)                                        MSLCONST    14
              READ(7)  (MD(LA),LA=1,NPTS)                                         MSLCONST    15
              READ(7)  (VMC(LA),LA=1,8)                                           MSLCONST    16
              READ(7)  (CDD(LA),LA=1,8)                                           MSLCONST    17
              READ(7)  (CNS(LA),LA=1,8)                                           MSLCONST    18
              READ(7)  (CNT(LA),LA=1,8)                                           MSLCONST    19
              READ(7)  (CNA(LA),LA=1,10)                                          MSLCONST    20
              READ(7)  ((ALPH(N1,N2),N1=1,10),N2=1,8)                             MSLCONST    21
              READ(7) LL,SA,WLIM,FOV,AS,TMAX,D1,TS,TR,AS,WN                       MSLCONST    22
              TS=.1                                                               MSLCONST    23
              SA=SA*RAD                                                           MSLCONST    24
              WLIM=WLIM*RAD                                                       MSLCONST    25
              FOV=FOV*RAD                                                         MSLCONST    26
              AS=AS*32.2                                                          MSLCONST    27
              READ(7) TGU,RMK,CKO,IONOM                                           MSLCONST    28
              READ(7)  (MISTYPE(LA),LA=1,2),BLURC,MMIN                            MSLCONST    29
              IF(MISTYPE(1).NE.MTS(1)) GO TO 6                                    MSLCONST    30
              IF(MISTYPE(2).NE.MTS(2)) GO TO 6                                    MSLCONST    31
              REWIND 7                                                            MSLCONST    32
              RETURN                                                              MSLCONST    33
              END                                                                 MSLCONST    34
```

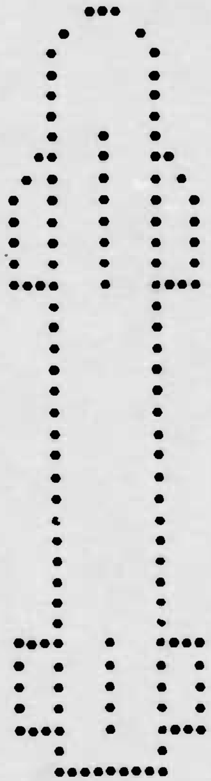
Table 1-2. Missile constants file

```
                              RUN   1

   MISSILE CONSTANTS

          MISSILE 1
                                SEEKER LOOK ANGLE (DEG)         84.
   SEEKER                       MAX GYRO RATE (DEG/SEC)        15.0
                                FIELD OF VIEW      (DEG)        1.9
                                GYRO TIME LAG      (SEC)        .06
        ----------------------------------------------------------------------
                                DETECTOR BANDWIDTH (MICRONS)
   SIGNAL PROCESSING            AIMPOINT TYPE 1 IRRADIANCE CENTROID
        ----------------------------------------------------------------------
                                NAVIGATION CONSTANT              4.0
                                NO GUIDANCE PERIOD  (SEC)        .2
   GUIDANCE UNIT                G - LIMIT           (G'S)        9.
                                MISSILE TIME CONST  (SEC)        .10
        ----------------------------------------------------------------------
                                MACH NUMBER
                                 .00  .22  .44  .70  .90 1.12 1.45 1.75
                        C(C)     .45  .47  .49  .52  .79 1.22 1.21 1.14
                        C(DB)    .07  .09  .11  .14  .22  .40  .25  .14
                        C(NMAX)  .00 2.85 2.90 3.30 3.52 3.98 3.44 3.44

                                                  C(N)
   AERODYNAMICS          MACH NO    .0   .2   .3   .6  1.0  1.4  1.8  2.2  2.8  3.6
                            .00     .0   .0   .0   .0   .0   .0   .0   .0   .0   .0
                            .22     .0  1.0  2.0  3.9  6.0  8.3 10.7 13.0 15.9 16.0
                            .44     .0   .9  1.8  3.6  5.5  7.7  9.9 12.5 15.7 16.0
                            .70     .0   .9  1.7  3.4  5.0  6.8  8.8 11.1 13.8 16.0
                            .90     .0   .8  1.7  3.3  4.8  6.3  8.2 10.4 13.0 15.7
                           1.12     .0   .7  1.4  2.9  4.5  6.0  7.6  9.5 11.9 14.3
                           1.45     .0  1.0  1.9  3.8  5.6  7.6  9.6 11.4 13.9 16.0
                           1.75     .0  1.0  2.0  4.0  6.0  8.0 10.0 12.0 14.0 16.0
        ----------------------------------------------------------------------
                                                  1     2     3     4
   MOTOR                 THRUST LEVEL       (LB)        0   250     0     0
                         SWITCHOVER TIME    (SEC)      .2   5.6   5.6   5.6
                         SPECIFIC IMPULSE   (1/SEC)  195.  195.  195.  195.
                         MOTOR WEIGHT DROP  (LB)       .0    .0    .0    .0
        ----------------------------------------------------------------------
   PHYSICAL CHARACTERISTICS                  OTHER CHARACTERISTICS
   DIAMETER                   (FT)   2.7/12  LIFESPAN              (SEC)       7.
   WEIGHT                     (LB)    20.3   LAUNCH VELOCITY       (FT/SEC)   75.
   MAX FLIPPER DEFLECTION (DEG) 17.0         MAX FLIPPER TRAVEL (DEG)          0.
-------------------------------------------------------------------------------
```



Guidance Unit

The guidance unit is composed of:

1. The navigation constant, variable name GKO
2. No guidance period (sec), variable name TB
3. G-limit (g's), variable name AS
4. Missile time constant (sec), variable name TS.

Aerodynamics

A sampling of eight values has been adopted for the parameters below to cover the broad range values in order of convenience in handling data information for table lookups. (Exceptions will be noted.) The following variables are functions of Mach number table, variable name VMC:

1. Chord force, variable name CDO.
2. Base drag coefficient, variable name CDB.
3. Maximum normal force coefficient, variable name CNT.
4. Angle of attack (deg) (80 samples), variable name ALPH. This parameter is a function of both mach number and normal force, variable name CNA.

Motor

The motor parameters are depicted as tables of 10 samples related to time. These are:

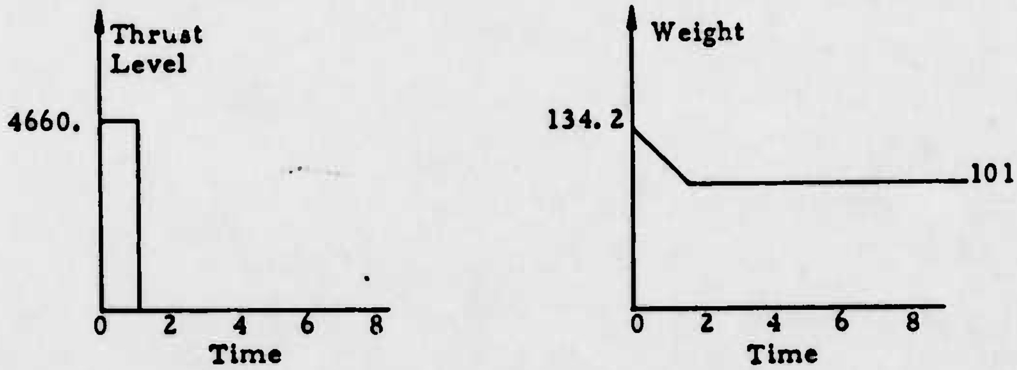
1. Time (sec.), variable name ST
2. Thrust (lb.), variable name TL
3. Specific impulse (1/sec.), variable name SIM
4. Motor weight drop (lb.), variable name WID.

See Table 1-3.

Table 1-3. Motor characteristics

Example:

Time	0.	1.	1.395	1.405	2.	4.	5.	6.	7.	8.
Thrust	4660.	4660.	4660.	0.	0.	0.	0.	0.	0.	0.
Specific Impulse	210.	210.	210.	210.	210.	210.	210.	210.	210.	210.
Motor Weight Drop	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.



Equations

1. Thrust = TL
2. Weight (new) = Weight (old) - Thrust (DELT/SIM) - WD(t)

DELT = Integration Step Size

Physical Characteristics

Physical characteristics of a missile are:

1. Diameter (in.), variable name DI
2. Weight (lb.), variable name W
3. Max. flipper deflection (deg.), variable name AG.

Other Characteristics

Other characteristics are:

1. Lifespan (sec.), variable name TMAX
2. Launch velocity (ft. /sec.), variable name X(Z)
3. Max. flipper travel (deg.), variable name FMAX.

Information not shown but required

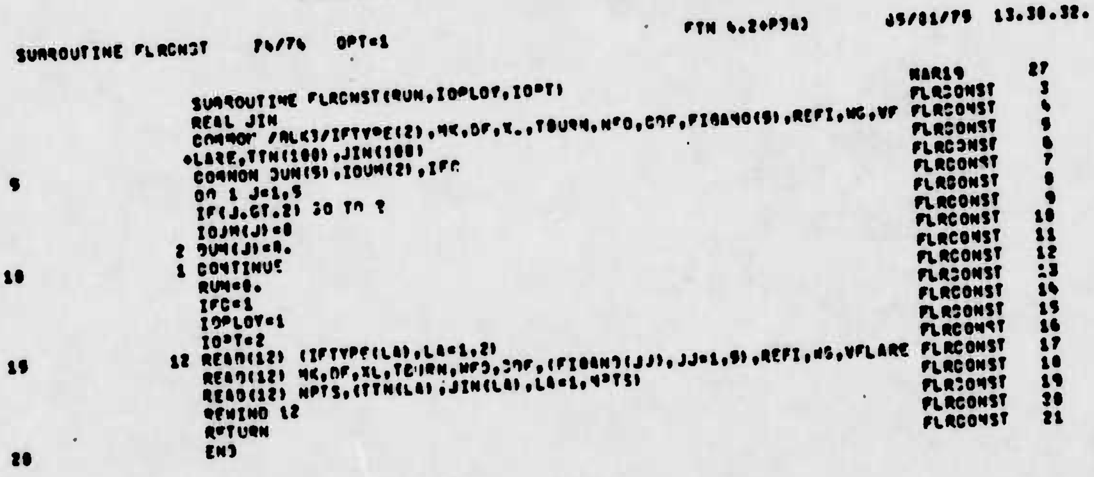
Information not shown but required is:

1. Missile kill radius used in part to determine probability of hit of missile, variable name RMK
2. Missile name, variable name MISTYPE
3. Blur circle, variable name BLURC
4. Minimum detectable irradiance, variable name HMIN.

FLARE FILE

The flare information has two categories: physical characteristics, and other characteristics. The flare file subroutine is presented as Table 1-4.

Table 1-4. Flare file subroutine



```
                                                          FTN 4.2+P383)      05/01/79  13.30.32.
SUBROUTINE FLRCNST     74/74   OPT=1
                                                                      MAR19      27
          SUBROUTINE FLRCNST(RUN,IOPLOT,IOPT)                         FLRCONST    3
          REAL JIN                                                    FLRCONST    4
          COMMON /BLK3/IFTYPE(2),MK,DF,X.,TBURN,NFO,COF,FIBAND(9),REFI,WG,VF FLRCONST    5
         +LARE,TTN(100),JIN(100)                                      FLRCONST    6
          COMMON DUM(5),IDUM(2),IFC                                   FLRCONST    7
          DO 1 J=1,5                                                  FLRCONST    8
          IF(J.GT.2) GO TO 2                                          FLRCONST    9
          IDUM(J)=0                                                   FLRCONST   10
        2 DUM(J)=0.                                                   FLRCONST   11
        1 CONTINUE                                                    FLRCONST   12
          RUN=0.                                                      FLRCONST   13
          IFC=1                                                       FLRCONST   14
          IOPLOT=1                                                    FLRCONST   15
          IOPT=2                                                      FLRCONST   16
       12 READ(12) (IFTYPE(LA),LA=1,2)                                FLRCONST   17
          READ(12) MK,DF,XL,TBURN,NFO,COF,(FIBAND(JJ),JJ=1,9),REFI,WG,VFLARE FLRCONST   18
          READ(12) NPTS,(TTN(LA),JIN(LA),LA=1,NPTS)                   FLRCONST   19
          REWIND 12                                                   FLRCONST   20
          RETURN                                                      FLRCONST   21
          END
```

Note that the program can handle pyrophorics if they are modelled as special flares, e.g. short rise time, short burn time, high peak intensity and high drag coefficient. However, the program may require some development to more fully take account of the burning and aerodynamic characteristics of this type of countermeasure.

Physical Characteristics

Physical characteristics are:

1. Diameter (in.), variable name DF
2. Length (in.), variable name XL
3. Weight (lb.), variable name WFO
4. Grain Weight (lb.), variable name WG.

Other Characteristics

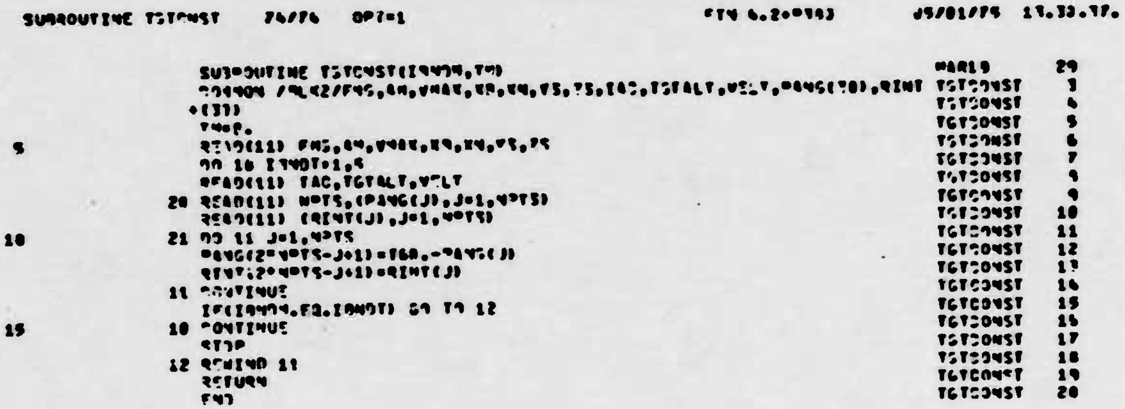
Other characteristics are:

1. Burn time (sec.), variable name TBURN
2. Reference intensity (watts/sterad), variable name REF
3. Spectral band constants, variable name FIBAND
4. Drag coefficient, variable name CDF
5. Dispenser ejection velocity (ft/sec), variable name VFLARE
6. Flare type (name), variable name IFTYPE
7. Type of surface area, variable name MK.

TARGET FILE

Target information has three categories: physical characteristics, initial condition, and other characteristics. Table 1-5 gives the target file subroutine.

Table 1-5. Target file subroutine



```
SUBROUTINE TGTCNST    74/74   OPT=1                    FTN 4.2+P393        05/01/75  13.33.37.

                SUBROUTINE TGTCNST(IRNDM,TM)                                       MARL9       29
                COMMON /BLK2/FMS,AM,VMAX,XR,XM,VS,TS,TAC,TGTALT,VELT,RANG(70),RINT TGTCONST    3
               +(70)                                                               TGTCONST    4
                TM=0.                                                              TGTCONST    5
                READ(11) FMS,AM,VMAX,XR,XM,VS,TS                                   TGTCONST    6
                DO 10 IRNDT=1,5                                                    TGTCONST    7
                READ(11) TAC,TGTALT,VELT                                           TGTCONST    8
             20 READ(11) NPTS,(RANG(J),J=1,NPTS)                                   TGTCONST    9
                READ(11) (RINT(J),J=1,NPTS)                                        TGTCONST   10
             21 DO 11 J=1,NPTS                                                     TGTCONST   11
                RANG(2*NPTS-J+1)=360.-RANG(J)                                      TGTCONST   12
                RINT(2*NPTS-J+1)=RINT(J)                                           TGTCONST   13
             11 CONTINUE                                                           TGTCONST   14
                IF(IRNDM.EQ.IRNDT) GO TO 12                                        TGTCONST   15
             10 CONTINUE                                                           TGTCONST   16
                STOP                                                               TGTCONST   17
             12 REWIND 11                                                          TGTCONST   18
                RETURN                                                             TGTCONST   19
                END                                                                TGTCONST   20
```

Physical Characteristics

Physical characteristics are:

1. Longitudinal distance from tailpipe to tip of tail (ft), variable name XB
2. Longitudinal distance from tailpipe to nose (ft.), variable name XN
3. Wingspan (ft.), variable name ZS.

Initial Condition

Initial condition is:

1. Maximum aircraft turn (g's), variable name FMG
2. Maximum aircraft forward acceleration (g's), variable name AM
3. Maximum aircraft speed (mach), variable name VM
4. Target altitude (ft.), variable name XP(8)
5. Target velocity (ft/sec.), variable name X(7).

Other Characteristics

Intensity as a function of polar angle are tables

1. Polar angle (deg.), variable name PANG
2. Intensity (kw/sterad), variable name RINT
3. Target type (name), variable name IAC.

ATMOSPHERE FILE

The last file to be discussed is the atmospheric spectral transmittance tables. These tables are a function of range, altitude, temperature, and band region for target and flare.

1. Range (ft.), variable name RNG
2. Atmospheric spectral transmittance of target, variable name TAUT
3. Atmospheric spectral transmittance of flare, variable name TAUF.

Table 1-6 gives the atmospher file subroutine.

Table 1-6. Atmosphere file subroutine

```
SUBROUTINE RVSTAU      74/74    OPT=1                    FTN 4.2+P399        05/01/79  13.30.39.

                    SUBROUTINE RVSTAU(TGTALT,IMNOM)                                  RVSTAUST    2
                    COMMON /BLK6/RNG(19),TAUT(19),TAUF(19)                           RVSTAUST    3
                    IF(TGTALT.LT.1000.) GO TO 13                                     RVSTAUST    4
                    IF(TGTALT.LT.21000.) GO TO 14                                    RVSTAUST    5
                    IALTA=3                                                          RVSTAUST    6
                    GO TO 15                                                         RVSTAUST    7
                 13 IALTA=1                                                          RVSTAUST    8
                    GO TO 15                                                         RVSTAUST    9
                 14 IALTA=2                                                          RVSTAUST   10
                 15 DO 16 LA=1,3                                                     RVSTAUST   11
                    DO 17 LB=1,5                                                     RVSTAUST   12
                    READ(16) IALTS,IMNOD                                             RVSTAUST   13
                    READ(16) (RNG(LC),TAUT(LC),TAUF(LC),LC=1,19)                     RVSTAUST   14
                    IF(IALTA.EQ.IALTS.AND.IMNOM.EQ.IMNOD) GO TO 19                   RVSTAUST   15
                 17 CONTINUE                                                         RVSTAUST   16
                 16 CONTINUE                                                         RVSTAUST   17
                    WRITE(6,18)                                                      RVSTAUST   18
                 18 FORMAT(1X,24HRANG-ALT. DO NOT COMPARE)                           RVSTAUST   19
                    STOP                                                             RVSTAUST   20
                 19 REWIND 16                                                        RVSTAUST   21
                    RETURN                                                           RVSTAUST   22
                    END                                                              RVSTAUST   23
```

DATA SOURCES

(1) J.A. Ratkovic, K. Nishimoto 'IRCM Simulation Study (U)' 4 Quarterly Progress Report prepared by Hughes Aircraft Company, Culver City, Calif. for Air Force Avionics Laboratory, Wright-Patterson Air Force Base, Ohio, July 1973

(2) IRCM Simulation Study (U), Feb. 1972, Volume II Hughes Aircraft Co., Culver City, CA, SDN G-5812

(3) Fighter-Launched Missiles (Trends), Eurasian Communist Countries (U), Dec. 1971, Defense Intelligence Agency, Report No. T65-09-26B, SDN J-58432

(4) DAWN (Develop Attack Warning Needs) (U), Final Report, Nov. 1972, General Research Corps., Santa Barbara, CA, SDN G-61305

(5) Foreign Material Exploitation Report, Interim Report, Project Graduation Level (U), July 1972, Missile Intelligence Agency, U.S. Army Missile Command, Redstone Arsenal, Alabama, SDN G-61357

(6) Shoulder Fired Surface to Air Missile System Comparison Summary (U), June 1972, Micom Foreign Intelligence Office, U.S. Army Missile Command, Redstone Arsenal, Alabama, SDN G-61358

(7) AIM-9D Simulation Parameters, Gene Younkin, Technical Note 4055-2-68, U.S. Naval Weapons Center, China Lake, Calif., Dec. 1967

(8) Hughes AIM-4D Aerodynamic Data, SRS-585, Revised 1 January 1965

(9) Assessment of Aerodynamic Studies of Foreign Tactical Missiles, Leroy Spearman and Charlie Jackson, Jr., NASA Langley Research Center, Hampton, Va., Feb. 1971

(10) ANAB Missile Wing Evaluation, FTD-CW-09-4-70, Feb. 1970.

Report on ASH Air-to-Air Missile Exploitation, Ministry of Defense, TM 88169, Dec. 1969.

(11) NAVWEPS Report TN 4063-233, AIM-9L Wind Tunnel Test Report (U), Oct. 1972

(12) PMS 12AD44-1/2174, Final Stability and Control Report for the AIM-54A Missile (U), 27 April 1973

(13) Radiometric Data and Mission Profile, Dept. of the Air Force, Headquarters Aeronautical Systems Division, Wright-Patterson AFB, Dec. 1972, SDN G-61377

(14) B-52 Infrared Radiation Patterns, Beoing Co., Wichita Division, July 1968, SDN J-59090

2. PROGRAM INITIALIZATION

This portion of the simulation program initializes all program constants, launch geometry variables, and determines the missile level angle computations. See Figure 2-1. Section 2.1 describes the initialization procedures, and Section 2.2 the lead angle computations.

2.1 PROGRAM INITIALIZATION

In the missile, target, flare simulation program, basic parameters have to be defined, and the program involved in doing this is initial. The three categories to be discussed will be definitions of constants, initialization, and launch geometry. A block diagram of these computations is shown in Figure 2-2. See Table 2-1 for program listing.

Definitions of Constants

The following constants are defined in the simulation program:

1. Gravity, (ft/sec.) variable name G, 32.2

2. Pi, variable name PI, 3.141592

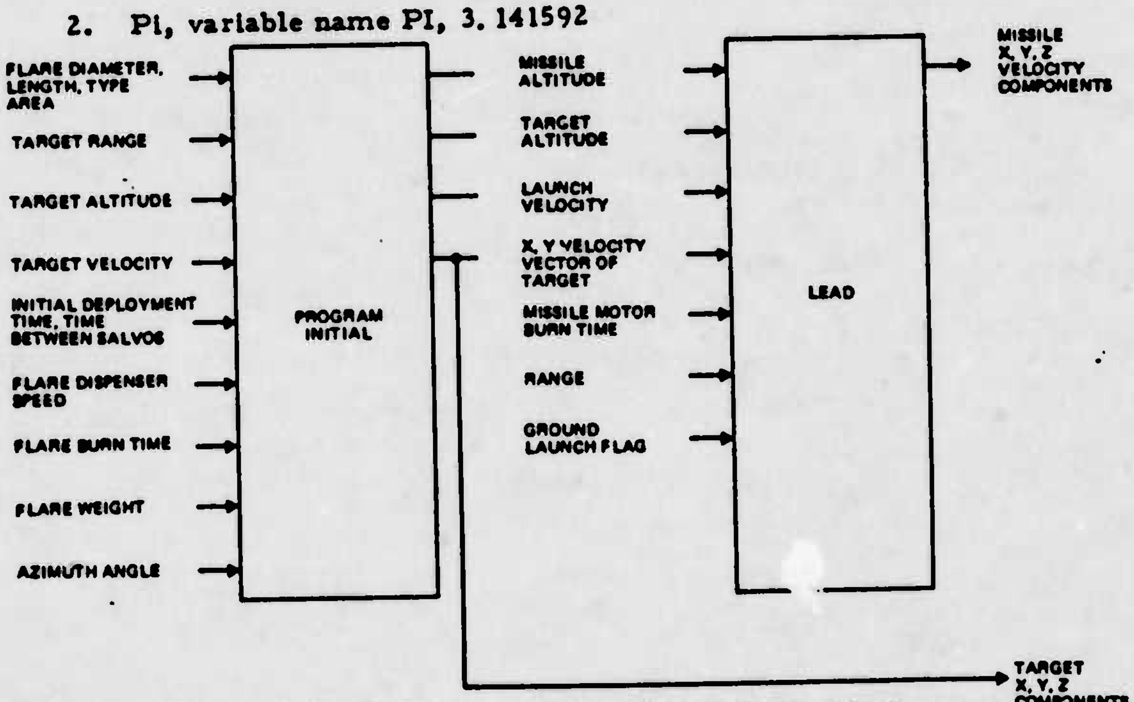
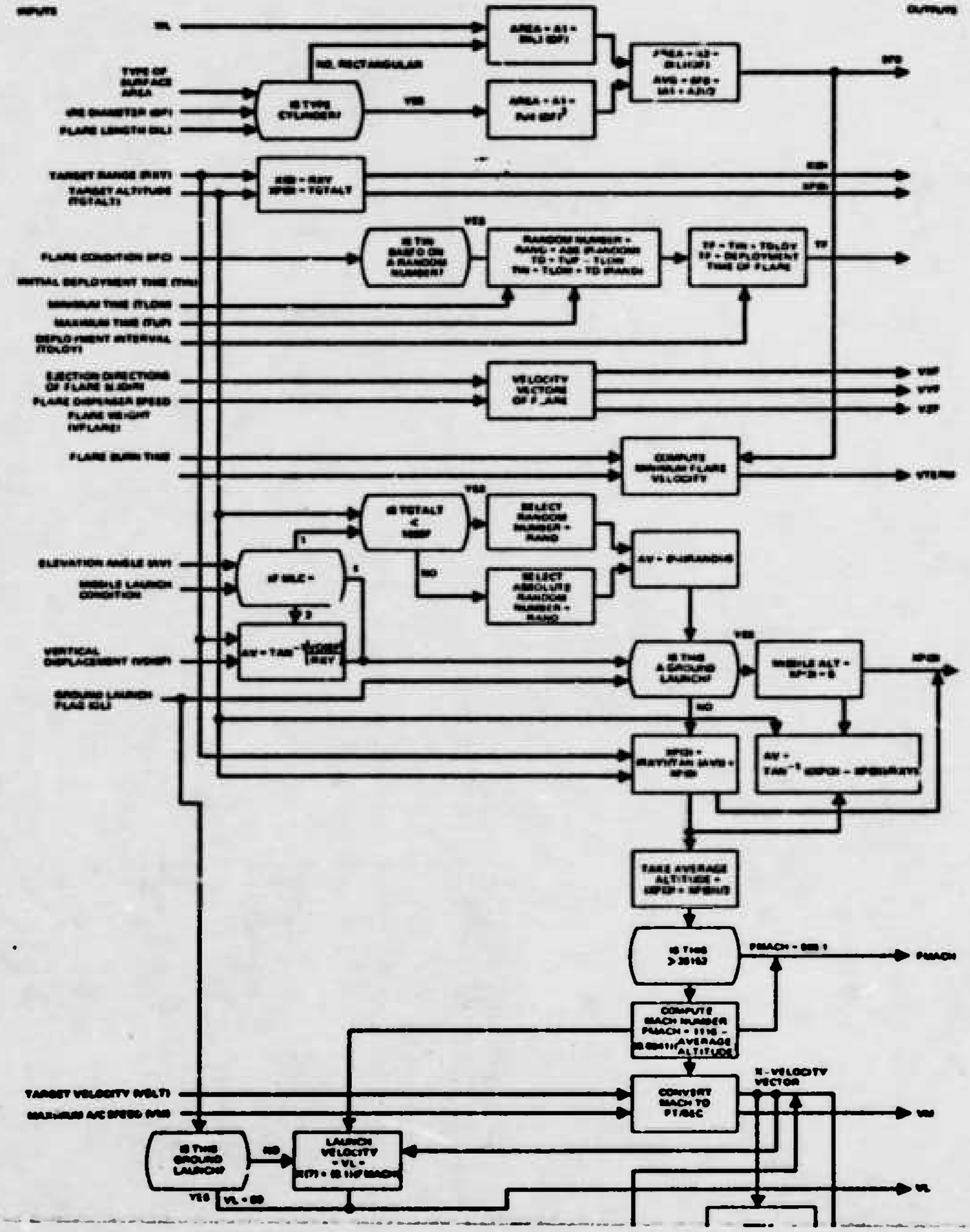


Figure 2-1. Programs initial and lead block diagram


INPUTS
OUTPUTS
TYPE OF SURFACE AREA
FLARE LENGTH (L)
IS TYPE CYLINDER?
NO, RECTANGULAR
YES
AREA = A1 =
AREA = A2 =
TARGET RANGE
TARGET ALTITUDE (TOTALT)
XPDI = TOTALT
FLARE CONDITION
INITIAL DEPLOYMENT TIME
MINIMUM TIME (TLOW)
MAXIMUM TIME (TUP)
DEPLOYMENT INTERVAL (TDLOY)
IS TIN BASED ON A RANDOM NUMBER?
RANDOM NUMBER = RAND
TF = TIN + TDLOY
TF = DEPLOYMENT TIME OF FLARE
TF
EJECTION DIRECTIONS OF FLARE
FLARE DISPENSER SPEED
FLARE WEIGHT (WFLARE)
VELOCITY VECTORS OF FLARE
FLARE BURN TIME
COMPUTE MINIMUM FLARE VELOCITY
VTERM
IS TOTALT <
SELECT RANDOM NUMBER = RAND
SELECT ABSOLUTE RANDOM NUMBER = RAND
NO
ELEVATION ANGLE
MISSILE LAUNCH CONDITION
IF MLC =
1
2
VERTICAL DISPLACEMENT
GROUND LAUNCH FLAG
IS THIS A GROUND LAUNCH?
YES
NO
MISSILE ALT =
AV = TAN⁻¹
TAKE AVERAGE ALTITUDE =
IS THIS > 36152
PMACH
COMPUTE MACH NUMBER
PMACH = 1116 −
AVERAGE ALTITUDE
X-VELOCITY VECTOR
TARGET VELOCITY
MAXIMUM A/C SPEED
CONVERT MACH TO FT/SEC
IS THIS GROUND LAUNCH?
NO
YES
VL = 0
LAUNCH VELOCITY = VL =
VL

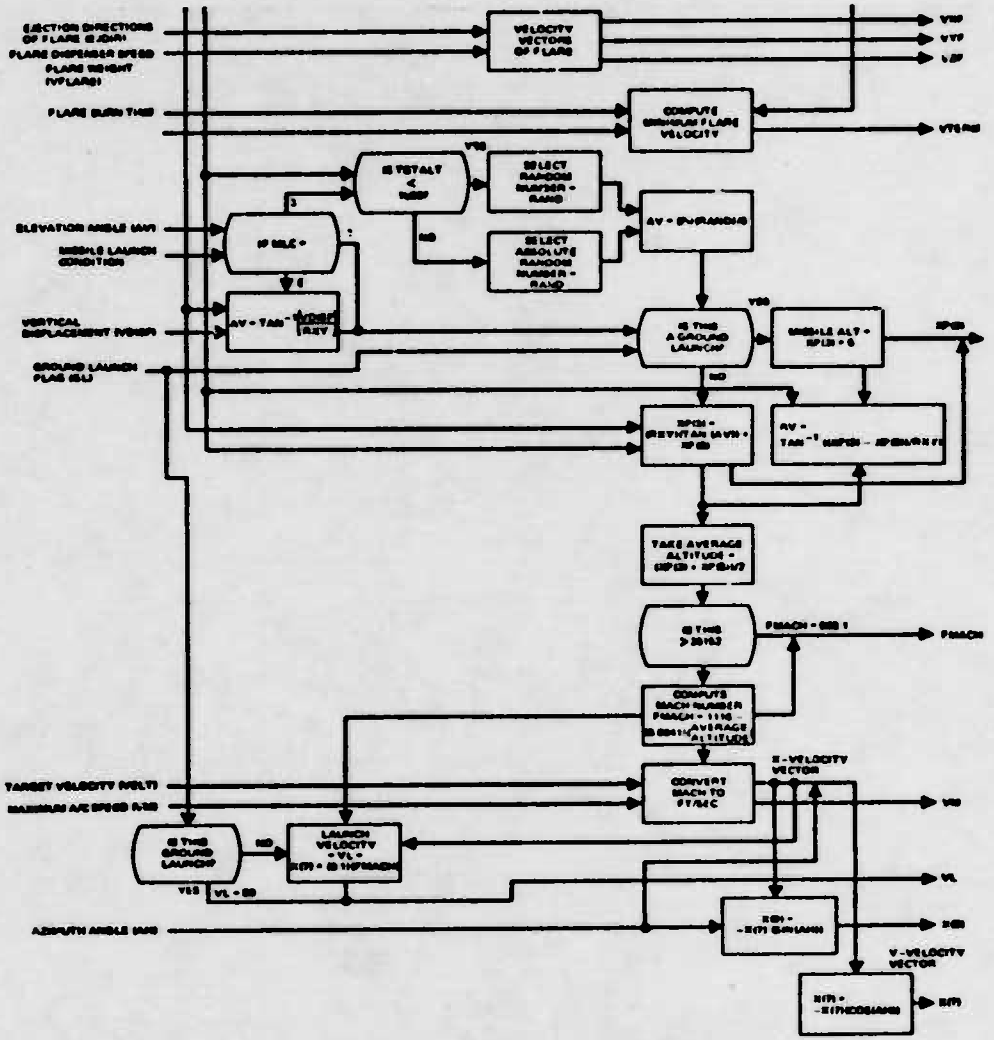


Figure 2-2. Program initial block diagram.

2

Table 2-1. Initial subroutine

```
SUBROUTINE INITIAL     74/74    OPT=1                          FTN 4.2+P398        05/01/75  13.38.41.

                     SUBROUTINE INITIAL(O1,TS,NK,DF,VELT,TOTALT,IAC,ISNDN,NPO,COF,IFTYP  INITIALT    2
                    +E,MISTYPE,VFLARE,W3,XL,TSDRN,VN,PMAC,EJDIR,TL,RJN,N9,NI)            INITIALT    3
                                                                                         INITIALT    4
                     COMMON SSW1,SSW2,SSW3,SSW4,DIAS,IDSPLAY,NSS1,IFC                    INITIALT    5
                     COMMON PI,RHO,W1,W2,DELT,TOLDV,TIN,WL                               INITIALT    6
                     COMMON DFLV,AM,REY,SFB,YUP,TLOW                                     INITIALT    7
                     COMMON MFLAR ,IFDIR(20),WLD,VNOISE,AV,FMACH,SL,G                    INITIALT    8
                     COMMON IGT(20,3)                                                    INITIALT    9
                     COMMON NM(20),LP,N                                                  INITIALT   10
                     COMMON TF(20),FSF(20),VTERM(20),SIN4,SIPN,SIJN,SIPNN,T,SI,SIP       INITIALT   11
                     COMMON VXF(20),VYF(20),VZF(20),Z(10),ZP(10),X(10),XP(10)            INITIALT   12
                     COMMON ZF(3,20),ZFP(3,20),XF(10,20),XFP(10,20),VT                   INITIALT   13
                     COMMON X20,X40,XP40,X70,X90,XP90,THRUST                             INITIALT   14
                     COMMON ALPHA,ALPHAP,TX,TY,TZ,DX,DY,DZ,AX,AV,AZ                      INITIALT   15
                     DIMENSION MISTYPE(2),IFTYPE(2),EJDIR(3)                             INITIALT   16
                     DIMENSION IX(20),IFX(20),TL(10)                                     INITIALT   17
                     WRITE(6,2)                                                          INITIALT   18
                   2 FORMAT(1H1)                                                         INITIALT   19
                     G=32.2                                                              INITIALT   20
                     PI=3.141592                                                         INITIALT   21
                     N=N                                                                 INITIALT   22
                     DF=.0086716                                                         INITIALT   23
                     WL=2.                                                               INITIALT   24
                     THRUST=TL(1)                                                        INITIALT   25
                     DO 1 J=1,216                                                        INITIALT   26
                   1 TF(J)=0.                                                            INITIALT   27
                     DO 3 J=1,60                                                         INITIALT   28
                     IF(J.GT.22) GO TO 3                                                 INITIALT   29
                     NM(J)=1                                                             INITIALT   30
                   3 IGT(J,1)=0                                                          INITIALT   31
                     RHO2=.002469                                                        INITIALT   32
                     DELT=.01                                                            INITIALT   33
                     CTR=.2/DELT                                                         MAR19      30
                     W2=CTR                                                              INITIALT   35
                     W1=W2                                                               INITIALT   36
                     GO TO (6,7,8,8), NK                                                 INITIALT   37
                   6 A1=16./144.*DF*XL                                                   INITIALT   38
                     A2=A1                                                               INITIALT   39
                     A3=DF*DF/144.                                                       INITIALT   40
                     FFL=(A1/4.+A2)/2.                                                   INITIALT   41
                     GO TO 40                                                            INITIALT   42
                   7 A1=PI*(DF/12.)*(DF/12.)*.25                                         INITIALT   43
                     GO TO 9                                                             INITIALT   44
                   8 A1=WL*DF*(1./12.)*(1./12.)                                          INITIALT   45
                   9 A2=XL*DF*(1./12.)*(1./12.)                                          INITIALT   46
                  40 SFB=(A1+A2)/2.                                                      INITIALT   47
                     X(5)=AKV                                                            INITIALT   48
                     X(7)=VELT                                                           INITIALT   49
                     X7=VELT                                                             INITIALT   50
                     XP(6)=TOTALT                                                        INITIALT   51
                     DFLV=1000.                                                          INITIALT   52
                     AM=AM*PI/180.                                                       INITIALT   53
                     GO TO (10,11), IFC                                                  MAR19      31
                  11 RAND=ABS(RANF(1))                                                   INITIALT   55
                     TD=TUP-TLOW                                                         INITIALT   56
                     TIN=TLOW+TD*RAND                                                    INITIALT   57
                  13 IF(SSW4.EQ.1.) GO TO 12                                             INITIALT   58
                     IF(X(7).GT..0) GO TO 13
```

Table 2-1 (Continued)

```
                                                                       FTN 4.2+P374.      03/31/75  13.33.41.
 SUBROUTINE INITIAL     74/74    OPT=1

                                                                                  INITIALT    59
                IPS=WMIL                                                          INITIALT    60
                GO TO 14                                                          INITIALT    61
             13 IPS=WMB/A                                                         INITIALT    62
             14 WRITE(13) RUN,NFLARE,(IFDIR(KJ),KJ=1,NFLARE),TAC,XP(4),AM,RXY,IPS, INITIALT    63
               +X(7)                                                              INITIALT    64
             12 GO TO (15,16,17), MLC                                             INITIALT    65
             15 AV=AV*PI/180.                                                     INITIALT    66
                GO TO 18                                                          INITIALT    67
             17 IF(XP(9).LT.1000.) GO TO 19                                       MAR19       32
                RAND=RANF(1)                                                      INITIALT    69
                GO TO 20                                                          MAR19       33
             19 RAND=ABS(RANF(1))                                                 INITIALT    71
             20 AV=PI*RAND/4.                                                     INITIALT    72
                GO TO 18                                                          INITIALT    73
             16 AV=ATAN2(VDIST,RXY)                                               INITIALT    74
             18 IF(GL.GT.0.) GO TO 21                                             INITIALT    75
                XP(3)=RXY*TAN(AV)+XP(4)                                           INITIALT    76
                GO TO 22                                                          INITIALT    77
             21 XP(3)=0.                                                          INITIALT    78
                AV=ATAN2((XP(3)-XP(4)),RXY)                                       INITIALT    79
             22 AVALT=(XP(3)+XP(4))/2.                                            INITIALT    80
                IF(AVALT.GT.36152.) GO TO 23                                      INITIALT    81
                FMACH=1116.-.0041*AVALT                                           INITIALT    82
                GO TO 24                                                          INITIALT    83
             23 FMACH=968.1                                                       INITIALT    84
             24 X(7)=X(7)*FMACH                                                   INITIALT    85
                X(3)=-X(7)*SIN(AM)                                                INITIALT    86
                IF(GL.EQ.0.) GO TO 6                                              INITIALT    87
                VL=0.                                                             INITIALT    88
                GO TO 5                                                           INITIALT    89
              6 VL=X(7)+.1*FMACH                                                  INITIALT    90
              5 X(7)=-X(7)*COS(AM)                                                INITIALT    91
                VM=VMAX*FMACH                                                     INITIALT    92
                RHO=RHOZ*EXP(-C7*(XP(8)))                                         INITIALT    93
                CONST=.5*RHO*CDFS                                                 INITIALT    94
                NFCNT=0                                                           INITIALT    95
                IFCNT=1                                                           INITIALT    96
                ICOMP=IFDIR(1)                                                    INITIALT    97
                DO 25 J=1,NFLARE                                                  INITIALT    98
                IF(ICOMP.EQ.IFDIR(J+1)) GO TO 95                                  INITIALT    99
                ICOMP=IFDIR(J+1)                                                  INITIALT   100
                NFCNT=NFCNT+1                                                     INITIALT   101
                IX(NFCNT)=IFCNT                                                   INITIALT   102
                IFCNT=1                                                           INITIALT   103
                IFX(NFCNT)=IFDIR(J)                                               INITIALT   104
                GO TO 25                                                          INITIALT   105
             95 IFCNT=IFCNT+1                                                     INITIALT   106
             25 CONTINUE                                                          INITIALT   107
                IF(NFCNT.NE.0) GO TO 27                                           INITIALT   108
                NFCNT=1                                                           INITIALT   109
                IX(NFCNT)=IFCNT                                                   INITIALT   110
             27 TMULT=0.                                                          INITIALT   111
                SS=0.                                                             INITIALT   112
                DO 28 K=1,30,NFCNT                                                INITIALT   113
                DO 29 KJ=1,NFCNT                                                  INITIALT   114
                IF(K+KJ-1.GT.20) GO TO 30                                         INITIALT   115
                ANG=FLOAT(IFX(KJ))*PI/180.
```

Table 2-1 (Continued)

```
   SUBROUTINE INITIAL     74/74    OPT=1                        FTN 4.2+P390 .      05/01/75  13.30.41.

                  VHF(K+KJ-1)=VFLARE*COS(ANG)                                            INITIALT  116
                  VIF(K+KJ-1)=VFLARE*SIN(ANG)                                            INITIALT  117
                  TF(K+KJ-1)=TIM+SS*TMULT                                                INITIALT  118
                  PSF(K+KJ-1)=IX(KJ)                                                     INITIALT  119
               29 CONTINUE                                                               INITIALT  120
                  SS=SS+1                                                                INITIALT  121
                  TMULT=TDLAY                                                            INITIALT  122
               28 CONTINUE                                                               INITIALT  123
               30 IF(IOSPLAY.EQ.0) GO TO 31                                              INITIALT  124
                  IPLNK=64                                                               INITIALT  125
                  IF(X7.GT..0) GO TO 32                                                  INITIALT  126
                  IPS=6HNIL                                                              INITIALT  127
                  GO TO 33                                                               INITIALT  128
               32 IPS=6HWA/R                                                             INITIALT  129
               33 WRITE(9,39) IPLNK,IAC,IPLNK,DL,XP(3),X7,XP(9),IPS,(IFDTR(K),K=1,2) INITIALT  130
                 +,IX(1),IDLOT,TIM,SKT,AM,AV                                             INITIALT  131
               39 FORMAT(1A6,6E12.6,A6,3I1,5I11.3)                                       INITIALT  132
               31 IF(SSW6.EQ.0.) GO TO 34                                                INITIALT  133
                  WRITE(13) AV,TDLOT,TIM,(IFTYPE(J),J=1,I),(MISTYPE(J),J=1,I)            INITIALT  134
               34 VH=SQRT(X(7)*X(7)+X(9)*X(9)+VTF(1)*VTF(1))                             INITIALT  135
                  VV=VIF(1)                                                              INITIALT  136
                  VTRM=100000.                                                           INITIALT  137
                  V=SQRT(VH*VH+VV*VV)                                                    INITIALT  138
                  TT=-DELT                                                               MAR19      34
                  NT=200./DELT+1                                                         MAR19      35
                  DO 35 ITM=1,NT                                                         MAR19      36
                  TT=TT+DELT                                                             MAR19      37
                  A=1.-TT/TBURN                                                          INITIALT  140
                  IF(NK.NE.6) GO TO 61                                                   INITIALT  141
                  AREA=AFL*A*A                                                           INITIALT  142
                  WE=WFO*A*A                                                             INITIALT  143
                  GO TO 62                                                               INITIALT  144
               61 AREA=SFO*A*A                                                           INITIALT  145
                  WE=WFO-WG*(1.-AREA/SFO)                                                INITIALT  146
               62 VHD=-CONST*AREA/WE*V*VH                                                INITIALT  147
                  VVD=-CONST*AREA/WE*V*VV-G                                              INITIALT  148
                  VH=VH+VHD*DELT                                                         INITIALT  149
                  VV=VV+VVD*DELT                                                         INITIALT  150
                  V=SQRT(VH*VH+VV*VV)                                                    INITIALT  151
                  IF(V.GT.VTRM) GO TO 36                                                 INITIALT  152
                  VTRM=V                                                                 INITIALT  153
               35 CONTINUE                                                               INITIALT  154
                  WRITE(6,37)                                                            INITIALT  155
               37 FORMAT(1X,24HMIN VELOCITY NOT REACHED)                                 INITIALT  156
                  STOP                                                                   INITIALT  157
               36 DO 38 J=1,20                                                           INITIALT  158
               38 VTERM(J)=VTRM                                                          INITIALT  159
                  RETURN                                                                 INITIALT  160
                  END                                                                    INITIALT  161
```

3. Air density at sea level, variable name RHOZ (slugs/ft^3) and coefficient of exponential variation with altitude, variable name CZ (ft^{-1})

4. Atmospheric density as a function of altitude, variable name RHO

5. Speed of sound as a function of altitude, variable name FMACH

6. Surface area, variable name SFB (ft^2).

Atmospheric density is given as:

RHO = RHOZ * EXP (-CZ * ALTITUDE)
RHOZ = STD air density (sea level)

where,

ALTITUDE = XP(8) = TARGET ALTITUDE

Speed of sound is a function of altitude. Altitude of missile and target are averaged and checked whether,

IF

Altitude > 36152, FMACH = 968.1

IF

Altitude ≤ 36152, FMACH = 1116.0 - 0.0041 * Altitude

Initialization

Pertinent missile, target and flare parameters, including position, velocity, and acceleration are initialized. Certain parameters previously defined by data file input are discussed in Section 1. They are:

1. Target range (ft.), variable name X(6)
2. Target velocity (ft/sec.), variable name X(7)
3. Target altitude (ft.), variable name XP(8)
4. Missile altitude (ft.), variable name XP(3).

Other required initial conditions are:

1. Elevation angle as a function of a random number (radians), variable name AV
2. Flare time between salvos (sec.), variable name TF
3. Flare dispenser ejection velocity components (ft. /sec.), variable name VXF, VYF, VZF
4. Minimum flare velocity (ft. /sec.), variable name VTERM.

Minimum flare velocity is precomputed here to be used later as a check on radiant intensity. This velocity is based on flare burn time, surface area, weight, and drag.

Launch Geometry

Options available for missile launch conditions are:

1. Input azimuth angle (AH) and horizontal range (RXY)(in which the program selects the elevation angle (AV) on a random basis.
2. Input azimuth angle, horizontal range, and elevation angle.
3. Input azimuth angle, horizontal range, and vertical displacement (Vdisp).

2.2 LEAD DETERMINATION

This subroutine computes initial velocity components for the missile at launch. Several alternate launch modes are available. Different launch modes may be used in the elevation and azimuth planes. See Figure 2-3 for a biock diagram description.

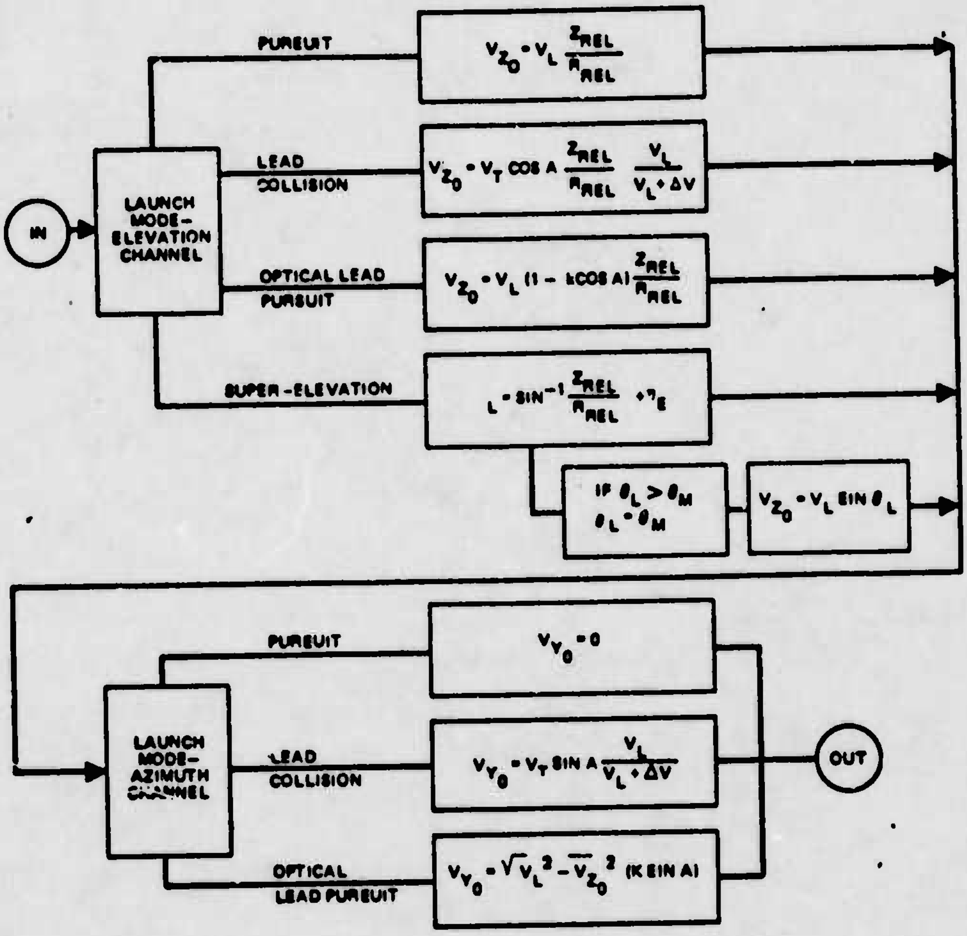

PURSUIT
$V_{Z_0} = V_L \frac{Z_{REL}}{R_{REL}}$
IN
LAUNCH MODE-ELEVATION CHANNEL
LEAD COLLISION
$V_{Z_0} = V_T \cos A \frac{Z_{REL}}{R_{REL}} \frac{V_L}{V_L + \Delta V}$
OPTICAL LEAD PURSUIT
$V_{Z_0} = V_L (1 - k\cos A) \frac{Z_{REL}}{R_{REL}}$
SUPER-ELEVATION
$_L = \sin^{-1} \frac{Z_{REL}}{R_{REL}} + \gamma_E$
IF $\theta_L > \theta_M$
$\theta_L = \theta_M$
$V_{Z_0} = V_L \sin \theta_L$
PURSUIT
$V_{Y_0} = 0$
LAUNCH MODE-AZIMUTH CHANNEL
LEAD COLLISION
$V_{Y_0} = V_T \sin A \frac{V_L}{V_L + \Delta V}$
OUT
OPTICAL LEAD PURSUIT
$V_{Y_0} = \sqrt{V_L^2 - V_{Z_0}^2}\ (K \sin A)$

Figure 2-3. Lead subroutine block diagram

The foliowing laws are available

1. Lead collision with maximum lead limit.
2. Pursuit
3. Visual lead pursuit with maximum lead limit.
4. Pursuit with super-elevation angle (elevation plane only).

Lead collision launch is based on attempting to put the missile on a collision course for a missile velocity of

$$V_L + \Delta V,$$

where V_L is launch velocity, and ΔV is an incremental velocity.

In pursuit launch, the missile is launched on a line directly toward the target. This mods is used when the launcher or the missile does not have capability for lead launch.

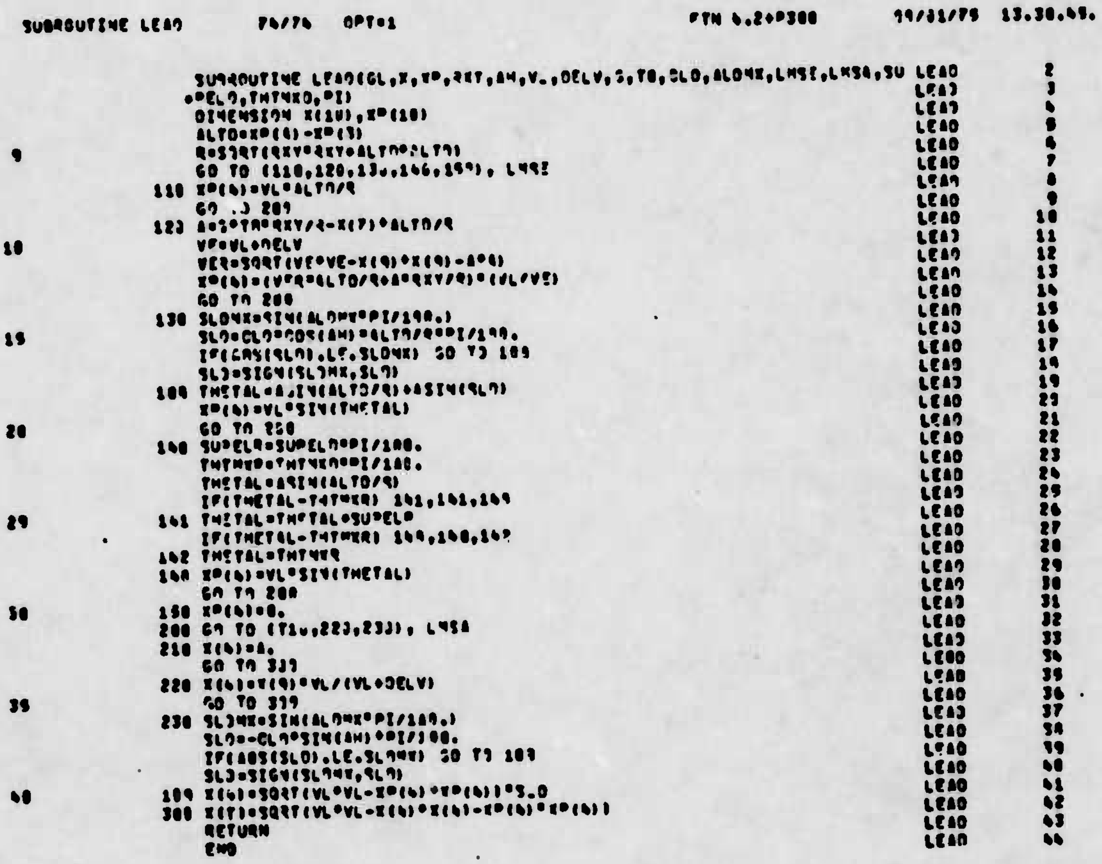
In visual lead pursuit, a lead angle is estimated by the person launching the missile. The value of lead is generally restricted to a small angle in this mode. The lead angle η_L is computed from

$$\text{Sin } \eta_L = K \sin A_T,$$

where A_T is target aspect angle, and K is an empirical constant ~ 0.5.

Often the missile is launched in a trajectory above the target. The angle above the angle of launch is called the super-elevation angle. The superelevation angle is input as a constant, with a limit on the total elevation angle of launch. A program listing is contained in Table 2-2.

Table 2-2. Lead subroutine



```
SUBROUTINE LEAD       74/74   OPT=1                        FTN 4.2+P380      09/11/75  13.30.49.

          SUBROUTINE LEAD(GL,X,XP,RXY,AM,VL,DELV,S,T0,SLO,ALOMX,LMSI,LMSA,SU LEAD    2
         +PELD,THTMXD,PI)                                                    LEAD    3
          DIMENSION X(10),XP(10)                                             LEAD    4
          ALTO=XP(6)-XP(3)                                                   LEAD    5
          R=SQRT(RXY*RXY+ALTO*ALTO)                                          LEAD    6
          GO TO (110,120,130,140,150), LMSI                                  LEAD    7
      110 XP(4)=VL*ALTO/R                                                    LEAD    8
          GO TO 200                                                          LEAD    9
      120 A=S*T0*RXY/R-X(7)*ALTO/R                                           LEAD   10
          VE=VL+DELV                                                         LEAD   11
          VER=SQRT(VE*VE-X(9)*X(9)-A*A)                                      LEAD   12
          XP(4)=(VER*ALTO/R+A*RXY/R)*(VL/VE)                                 LEAD   13
          GO TO 200                                                          LEAD   14
      130 SLOMX=SIN(ALOMX*PI/180.)                                           LEAD   15
          SLO=GLO*COS(AM)*ALTO/R*PI/180.                                     LEAD   16
          IF(ABS(SLO).LE.SLOMX) GO TO 180                                    LEAD   17
          SLO=SIGN(SLOMX,SLO)                                                LEAD   18
      180 THETAL=ASIN(ALTO/R)+ASIN(SLO)                                      LEAD   19
          XP(4)=VL*SIN(THETAL)                                               LEAD   20
          GO TO 200                                                          LEAD   21
      140 SUPELR=SUPELD*PI/180.                                              LEAD   22
          THTMXR=THTMXD*PI/180.                                              LEAD   23
          THETAL=ASIN(ALTO/R)                                                LEAD   24
          IF(THETAL-THTMXR) 141,141,149                                      LEAD   25
      141 THETAL=THETAL+SUPELR                                               LEAD   26
          IF(THETAL-THTMXR) 149,149,142                                      LEAD   27
      142 THETAL=THTMXR                                                      LEAD   28
      149 XP(4)=VL*SIN(THETAL)                                               LEAD   29
          GO TO 200                                                          LEAD   30
      150 XP(4)=0.                                                           LEAD   31
      200 GO TO (210,220,230), LMSA                                          LEAD   32
      210 X(4)=A.                                                            LEAD   33
          GO TO 300                                                          LEAD   34
      220 X(4)=X(9)*VL/(VL+DELV)                                             LEAD   35
          GO TO 300                                                          LEAD   36
      230 SLOMX=SIN(ALOMX*PI/180.)                                           LEAD   37
          SLO=-GLO*SIN(AM)*PI/180.                                           LEAD   38
          IF(ABS(SLO).LE.SLOMX) GO TO 189                                    LEAD   39
          SLO=SIGN(SLOMX,SLO)                                                LEAD   40
      189 X(4)=SQRT(VL*VL-XP(4)*XP(4))*S.O                                   LEAD   41
      300 X(7)=SQRT(VL*VL-X(4)*X(4)-XP(4)*XP(4))                             LEAD   42
          RETURN                                                             LEAD   43
          END                                                                LEAD   44
```

3. DYNAMICS

Figure 3-1 is a block diagram of the major components of the simulation program and shows the dynamics computations to be performed. Basically, the dynamics portion of the simulation program determines the X-, Y-, and Z-components of acceleration, velocity, and position for for the missile, target, and flare(s).

The forces controlling the missile trajectory are thrust, chord, commanded, and gravity. The missile velocity and position are computed by integrating the total acceleration.

The target is considered to fly nominally straight and level, i.e., no maneuver. However, the program does allow for three maneuver options: (1) turn in any direction, (2) straight acceleration, and (3) turn with acceleration.

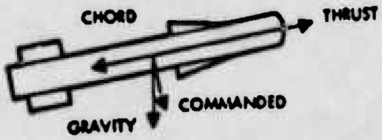
When the flare(s) is deployed, the flare deployment strategy controls how many are deployed, in what direction they are deployed, and how often they are deployed. The forces which govern the flare motion are drag and gravity.

3.1 MISSILE DYNAMICS

The missile equations of motion are governed by the four forces shown in Table 3-1. This table also lists the X-, Y-, and Z- components of each force. Figure 3-2 shows a block diagram of the computations performed in this portion of the program. Basically, the missile dynamics are updated as follows:

1. The aimpoint position is fed into the gyro subroutine from which gyro position and rate are output.
2. These gyro rates and positions are then fed into a subroutine which simulates the guidance unit of the missile and computes the acceleration components which are to be commanded by the missile.
3. The acceleration components due to thrust and chord forces are subsequently computed and resolved.

Table 3-1. Forces acting on the missile



FORCE	X COMPONENT	Y COMPONENT	Z COMPONENT
THRUST	$\frac{THRUST \cdot COS(\gamma+\alpha)}{\left[1+COS^2(\gamma+\alpha)\,TAN^2(\gamma'+\alpha')\right]^{1/2}}$	$\frac{THRUST \cdot SIN(\gamma+\alpha)}{\left[1+COS^2(\gamma+\alpha)\,TAN^2(\gamma'+\alpha')\right]^{1/2}}$	$\frac{THRUST \cdot COS(\gamma+\alpha) \cdot TAN(\gamma'+\alpha')}{\left[1+COS^2(\gamma+\alpha) \cdot TAN^2(\gamma'+\alpha')\right]^{1/2}}$
CHORD	$-1/2\,\rho C_c\,\pi\,(D_M/2)^2 V^2$ $\cdot \frac{COS(\gamma+\alpha)}{\left[1+COS^2(\gamma+\alpha)\,TAN^2(\gamma'+\alpha')\right]^{1/2}}$	$-1/2\,\rho C_c\,\pi\,(D_M/2)^2 V^2$ $\cdot \frac{SIN(\gamma+\alpha)}{\left[1+COS^2(\gamma+\alpha)\,TAN^2(\gamma'+\alpha')\right]^{1/2}}$	$-1/2\,\rho C_c\,\pi\,(D_M/2)^2 V^2$ $\cdot \frac{COS(\gamma+\alpha)\,TAN(\gamma'+\alpha')}{\left[1+COS^2(\gamma+\alpha)\,TAN^2(\gamma'+\alpha')\right]^{1/2}}$
COMMANDED	$-\left[\frac{AW\,I\dot{\phi}}{G\left[1+COS^2\phi = TAN^2\phi'\right]}\right]^{1/2}$ $= \left[\frac{SIN(\gamma+\alpha)}{COS(\gamma-\phi+\alpha)} + \frac{SIN(\gamma'+\alpha')}{COS(\gamma'-\phi'+\alpha')}\right]$	$\frac{AI\dot{\phi}W}{GCOS(\gamma-\phi-\alpha)} \cdot COS(\gamma+\alpha)$ $\cdot \frac{1}{\left[1+COS^2\phi \cdot TAN^2(\phi')\right]^{1/2}}$	$\frac{AI\dot{\phi}W}{G\,COS(\gamma'-\phi'+\alpha')}$ $\cdot \frac{COS\phi\ /\ COS\phi'}{\left[1+COS^2\phi \cdot TAN^2\phi'\right]^{1/2}}$
GRAVITY	0	0	W ·

G = GRAVITATIONAL CONSTANT

D_M = MISSILE DIAMETER

ρ = ATMOSPHERIC DENSITY

A = NAVIGATION PARAMETER

W = MISSILE WEIGHT

C_c = CHORD COEFFICIENT

4. The missile acceleration components due to thrust, chord, commanded and gravity forces are summed to obtain the X-, Y-, and Z-missile acceleration components.

5. These components are then integrated to obtain the missile velocity components.

6. Finally, these velocity components are subsequently integrated to obtain missile position.

The remainder of this Section describes the gyro position and rate computations, the thrust computations, the chord force computations, and the commanded acceleration computations in detail. Table 3-2 shows the portion of the main program which involves the missile dynamics computations.

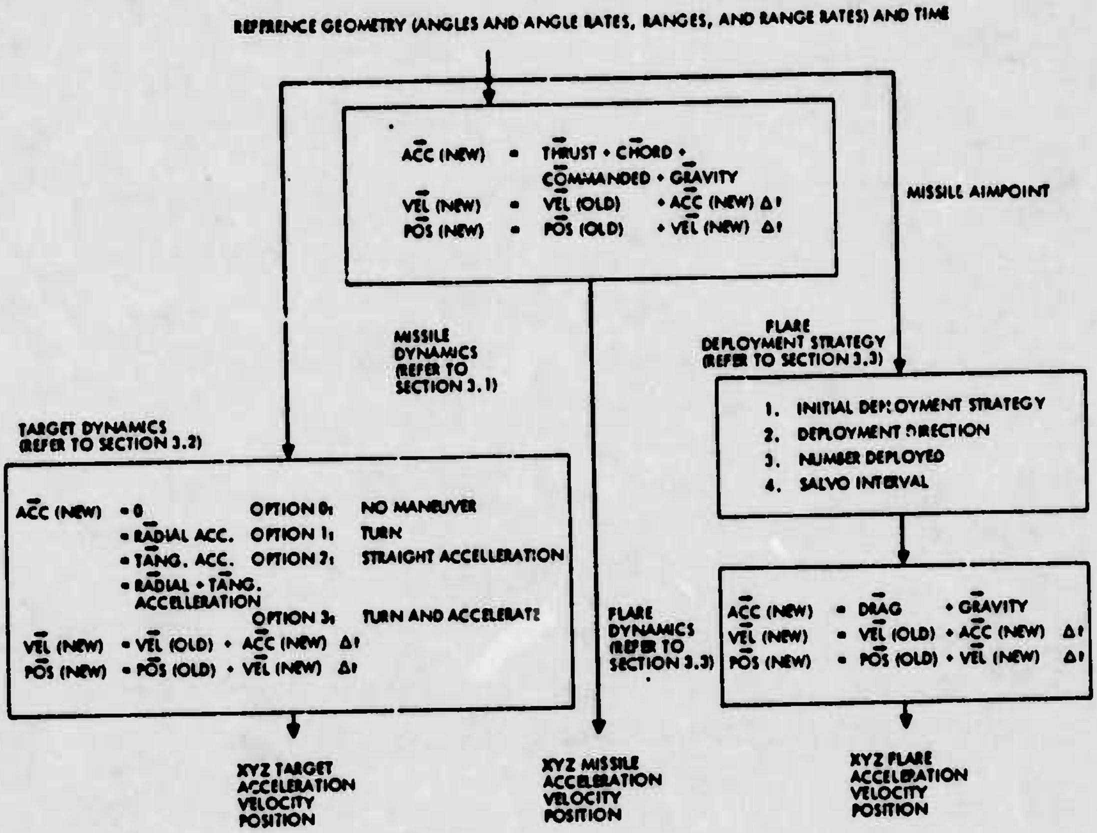
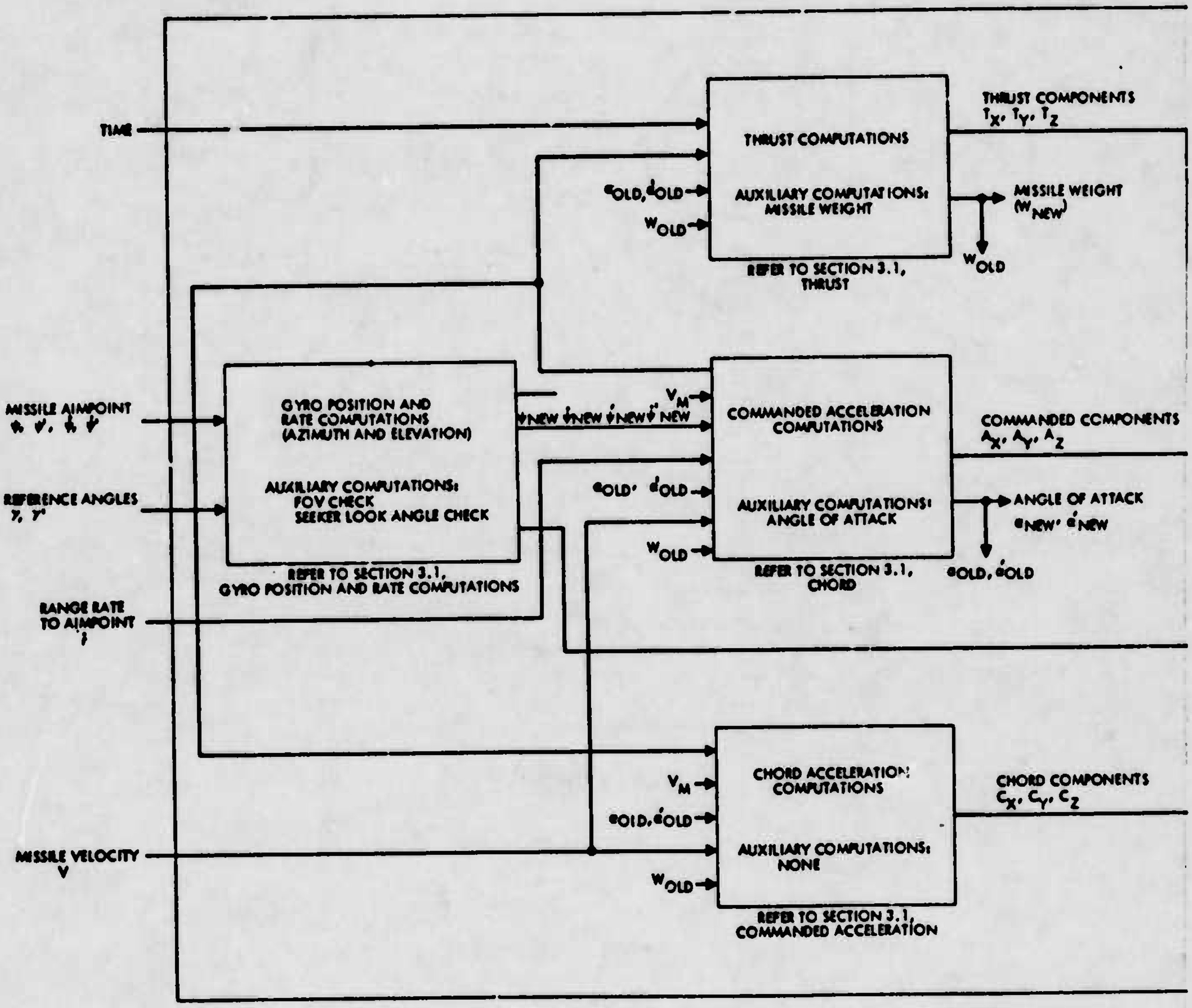
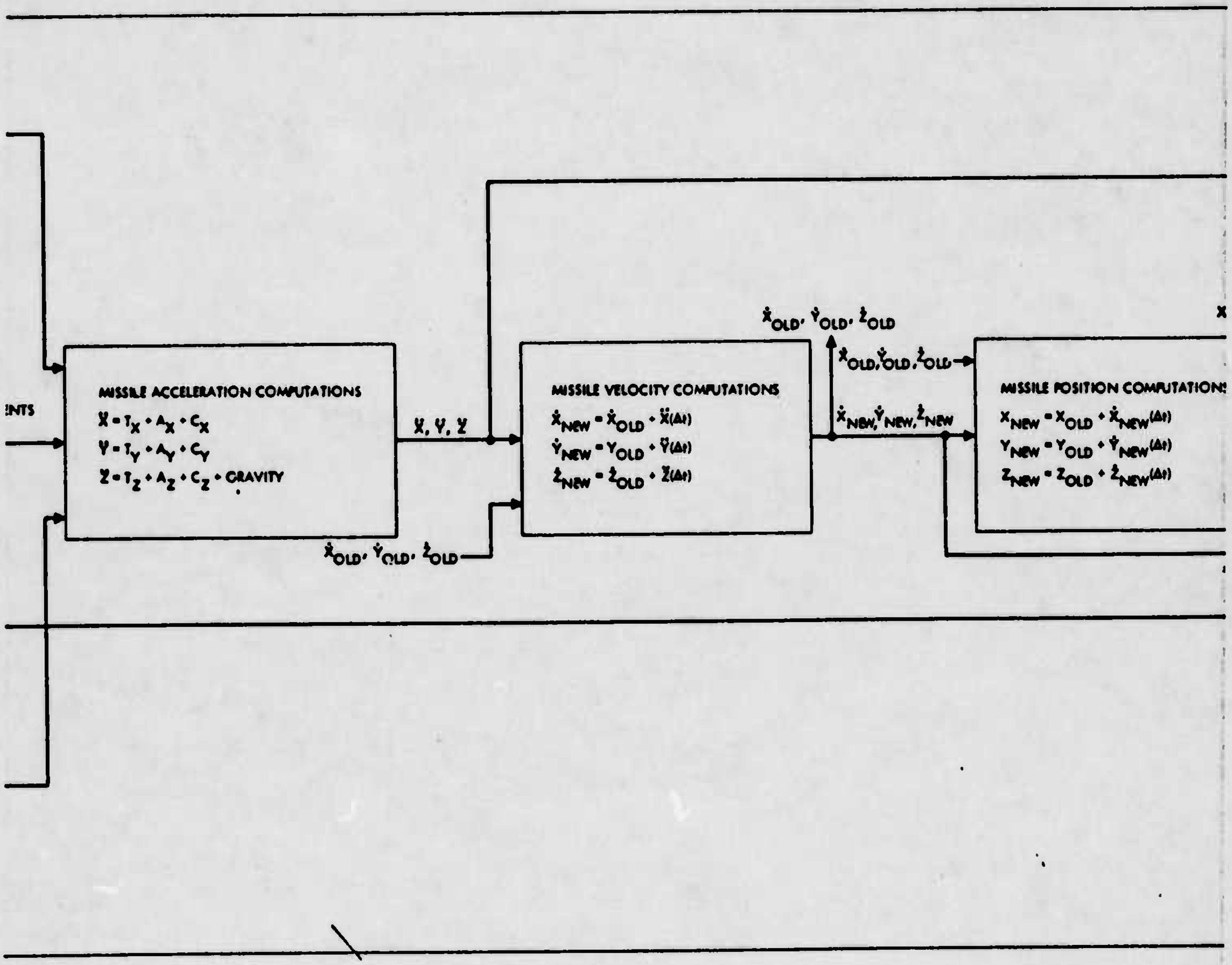

REFERENCE GEOMETRY (ANGLES AND ANGLE RATES, RANGES, AND RANGE RATES) AND TIME
ACC (NEW) = THRUST + CHORD + COMMANDED + GRAVITY
VEL (NEW) = VEL (OLD) + ACC (NEW) Δt
POS (NEW) = POS (OLD) + VEL (NEW) Δt
MISSILE AIMPOINT
MISSILE DYNAMICS (REFER TO SECTION 3.1)
FLARE DEPLOYMENT STRATEGY (REFER TO SECTION 3.3)
1. INITIAL DEPLOYMENT STRATEGY
2. DEPLOYMENT DIRECTION
3. NUMBER DEPLOYED
4. SALVO INTERVAL
TARGET DYNAMICS (REFER TO SECTION 3.2)
ACC (NEW) = 0 OPTION 0: NO MANEUVER
= RADIAL ACC. OPTION 1: TURN
= TANG. ACC. OPTION 2: STRAIGHT ACCELLERATION
= RADIAL + TANG. ACCELLERATION OPTION 3: TURN AND ACCELERATE
VEL (NEW) = VEL (OLD) + ACC (NEW) Δt
POS (NEW) = POS (OLD) + VEL (NEW) Δt
FLARE DYNAMICS (REFER TO SECTION 3.3)
ACC (NEW) = DRAG + GRAVITY
VEL (NEW) = VEL (OLD) + ACC (NEW) Δt
POS (NEW) = POS (OLD) + VEL (NEW) Δt
XYZ TARGET ACCELERATION VELOCITY POSITION
XYZ MISSILE ACCELERATION VELOCITY POSITION
XYZ FLARE ACCELERATION VELOCITY POSITION

Figure 3-1. Dynamics


TIME
THRUST COMPUTATIONS
AUXILIARY COMPUTATIONS: MISSILE WEIGHT
$\alpha_{OLD}, \dot{\alpha}_{OLD}$
W_{OLD}
REFER TO SECTION 3.1, THRUST
THRUST COMPONENTS T_X, T_Y, T_Z
MISSILE WEIGHT (W_{NEW})
W_{OLD}
MISSILE AIMPOINT $\theta, \psi, \dot{\theta}, \dot{\psi}$
REFERENCE ANGLES γ, γ'
GYRO POSITION AND RATE COMPUTATIONS (AZIMUTH AND ELEVATION)
AUXILIARY COMPUTATIONS: FOV CHECK SEEKER LOOK ANGLE CHECK
REFER TO SECTION 3.1, GYRO POSITION AND RATE COMPUTATIONS
$\theta_{NEW}\ \psi_{NEW}\ \dot{\theta}_{NEW}\ \dot{\psi}_{NEW}$
V_M
COMMANDED ACCELERATION COMPUTATIONS
$\alpha_{OLD}, \dot{\alpha}_{OLD}$
AUXILIARY COMPUTATIONS: ANGLE OF ATTACK
W_{OLD}
REFER TO SECTION 3.1, CHORD
COMMANDED COMPONENTS A_X, A_Y, A_Z
ANGLE OF ATTACK $\alpha_{NEW}, \dot{\alpha}_{NEW}$
$\alpha_{OLD}, \dot{\alpha}_{OLD}$
RANGE RATE TO AIMPOINT $\dot{r}$
MISSILE VELOCITY V
V_M
CHORD ACCELERATION COMPUTATIONS
$\alpha_{OLD}, \dot{\alpha}_{OLD}$
AUXILIARY COMPUTATIONS: NONE
W_{OLD}
REFER TO SECTION 3.1, COMMANDED ACCELERATION
CHORD COMPONENTS C_X, C_Y, C_Z


ENTS
MISSILE ACCELERATION COMPUTATIONS
$\ddot{X} = T_X + A_X + C_X$
$\ddot{Y} = T_Y + A_Y + C_Y$
$\ddot{Z} = T_Z + A_Z + C_Z + \text{GRAVITY}$
$\ddot{X}, \ddot{Y}, \ddot{Z}$
$\dot{X}_{OLD}, \dot{Y}_{OLD}, \dot{Z}_{OLD}$
MISSILE VELOCITY COMPUTATIONS
$\dot{X}_{NEW} = \dot{X}_{OLD} + \ddot{X}(\Delta t)$
$\dot{Y}_{NEW} = Y_{OLD} + \ddot{Y}(\Delta t)$
$\dot{Z}_{NEW} = \dot{Z}_{OLD} + \ddot{Z}(\Delta t)$
$\dot{X}_{OLD}, \dot{Y}_{OLD}, \dot{Z}_{OLD}$
$\dot{X}_{OLD}, \dot{Y}_{OLD}, \dot{Z}_{OLD}$
$\dot{X}_{NEW}, \dot{Y}_{NEW}, \dot{Z}_{NEW}$
MISSILE POSITION COMPUTATIONS
$X_{NEW} = X_{OLD} + \dot{X}_{NEW}(\Delta t)$
$Y_{NEW} = Y_{OLD} + \dot{Y}_{NEW}(\Delta t)$
$Z_{NEW} = Z_{OLD} + \dot{Z}_{NEW}(\Delta t)$
X

Fi

7

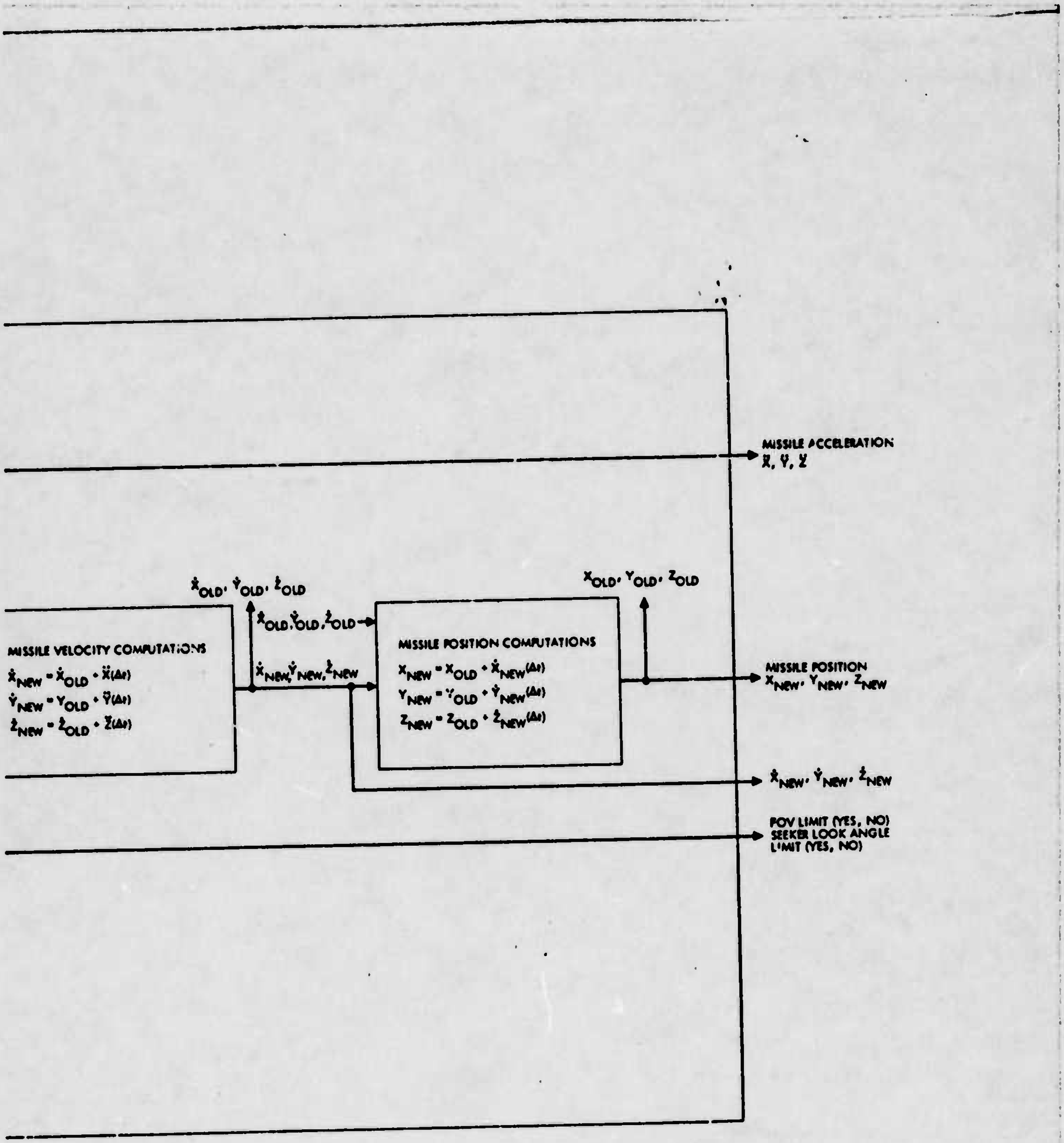

MISSILE ACCELERATION
$\ddot{X}, \ddot{Y}, \ddot{Z}$
$\dot{X}_{OLD}, \dot{Y}_{OLD}, \dot{Z}_{OLD}$
$X_{OLD}, Y_{OLD}, Z_{OLD}$
$\dot{X}_{OLD}, \dot{Y}_{OLD}, \dot{Z}_{OLD}$
MISSILE VELOCITY COMPUTATIONS
$\dot{X}_{NEW} = \dot{X}_{OLD} + \ddot{X}(\Delta t)$
$\dot{Y}_{NEW} = Y_{OLD} + \ddot{Y}(\Delta t)$
$\dot{Z}_{NEW} = \dot{Z}_{OLD} + \ddot{Z}(\Delta t)$
$\dot{X}_{NEW}, \dot{Y}_{NEW}, \dot{Z}_{NEW}$
MISSILE POSITION COMPUTATIONS
$X_{NEW} = X_{OLD} + \dot{X}_{NEW}(\Delta t)$
$Y_{NEW} = Y_{OLD} + \dot{Y}_{NEW}(\Delta t)$
$Z_{NEW} = Z_{OLD} + \dot{Z}_{NEW}(\Delta t)$
MISSILE POSITION
$X_{NEW}, Y_{NEW}, Z_{NEW}$
$\dot{X}_{NEW}, \dot{Y}_{NEW}, \dot{Z}_{NEW}$
FOV LIMIT (YES, NO)
SEEKER LOOK ANGLE
LIMIT (YES, NO)

Figure 3-2. Missile dynamics block diagram

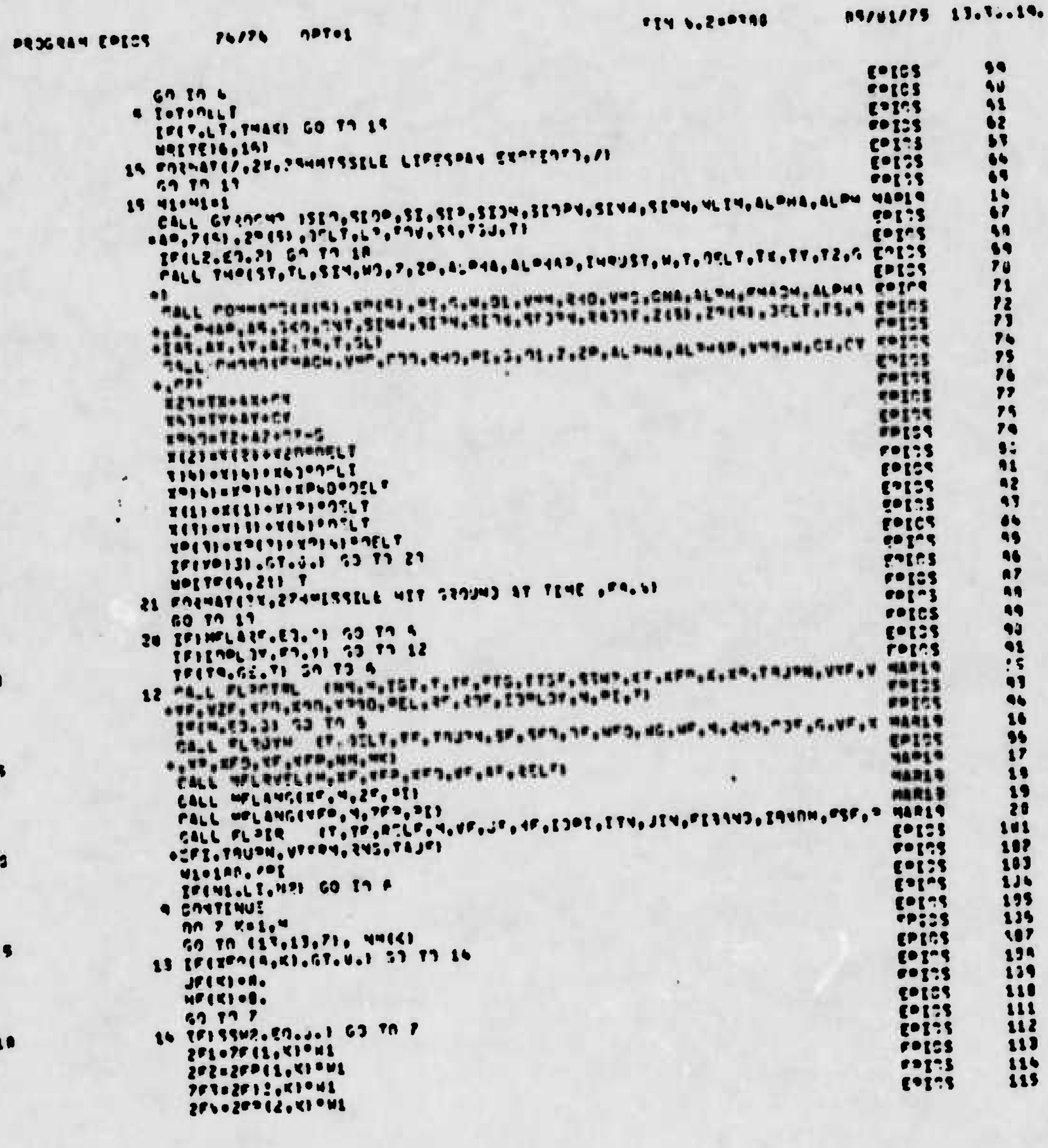
3

Table 3-2. Executive routine showing missile/dynamics computations

```
PROGRAM EPICS      74/74    OPT=1                           FTN 4.2+P380       03/31/75  13.38.19.

                 PROGRAM EPICS(INPUT,OUTPUT,TAPE12,TAPE7,TAPE9,TAPE10,TAPE11,TAPE14 EPICS         2
                1         ,TAPE5=INPUT,TAPE6=OUTPUT)                                  EPICS         3
                 REAL JF,JIM                                                          EPICS         4
                 DIMENSION MF(20),MTS(2),NF(20),RTLF(9,20),RIL(12),IJDIR(8)           EPICS         5
                 DIMENSION SF(20),HF(20),JF(20),VF(20)                                EPICS         6
                 DIMENSION RF(20),RDF(20),TTGF(20),XFD(10,20)                         EPICS         7
                 COMMON /BLK1/ST(10),TL(10),SIM(10),MD(10),VMC(8),CDC(8),CNT(8),CMA   EPICS         8
                +(10),ALPM(10,8),LL,SA,DLTM,FOV,AS,TMAX,D1,T9,T8,A6,NM,TGU,RNK,GKO,   EPICS         9
                +ISNOM,MISTYPE(2),BLURR,MMIN,[illegible](9)                           EPICS        10
                 COMMON /BLK2/FMS,AM,VMAX,X9,XN,YS,ZS,IAD,TGTALT,VELT,PANG(30),RINT   EPICS        11
                +(30)                                                                 EPICS        12
                 COMMON /BLK3/IFTYPE(2),MK,DF,RL,TBURN,NFO,COF,FIRANG(5),RIFI,NG,VF   EPICS        13
                +LARE,TTM(100),JIM(100)                                               EPICS        14
                 COMMON /BLK4/RNG(10),TAUT(10),TAUF(10)                               EPICS        15
                 COMMON SSM1,SSM2,SSM3,SSM4,BIAS,IDSPLAT,MSS1,IFC                     EPICS        16
                 COMMON PI,RHO,N1,NP,DF,T,VOLDT,TIM,V.                                EPICS        17
                 COMMON DELV,AM,RXY,SFP,TUP,TLOW                                      EPICS        18
                 COMMON NFLARE,TFOTP(20),MLD,VRISE,AV,FNORM,G.,G                      EPICS        19
                 COMMON IGT(20,3)                                                     EPICS        20
                 COMMON NN(20),L2,N                                                   EPICS        21
                 COMMON TF(20),FSF(20),VTFR(20),STNM,SIM,SIOM,SIOPM,T,SI,SIP          EPICS        22
                 COMMON VXF(20),VYF(20),VZF(20),Z(10),ZP(10),X(10),XP(10)             EPICS        23
                 COMMON PF(3,20),ZFP(3,20),XF(10,20),XFP(10,20),VT                    EPICS        24
                 COMMON X20,X40,XP40,X70,X90,XP90,THRUST                              EPICS        25
                 COMMON ALPHA,ALPHAP,TX,TY,TZ,GX,GY,GZ,AX,AY,AZ                       EPICS        26
                 NAMELIST/PARAM/SSM1,SSM3,ISNOM,NFO,SA,M,TM,FOV,AS,TMAX,              MAR19         1
                +GKO,D1,T9,T8,A6,W,IOPT,NG,TM,X,XP,L.,COF,PINT,PANG,                  MAR19         2
                +CMA,MMIN,VMC,CDC,CNT,TBURN,TGU,IEND,XGAIN,VFLARE,GL,                 MAR19         3
                +RXY,AM,BIAS,TLOW,TUP,AV,VRISE,MLD,IFC,TIM,FOLOV,REFT,                MAR19         4
                +IDSPLAT,ST,TOPLOV,PF,RDF,TTGF,SUPELD,THTMXD,.MSS,                    MAR19         5
                +LMSA,CLD,TL,SIM,VD,MTC,RUN,ALOMX,SSM2,SSM4,FMG,                      MAR19         6
                +TGTALT,VELT,XN,YN,YS,ZS                                              MAR19         7
                 DATA(RJDIR(J),J=1,8)/90.,270.,0.,180.,45.,135.,225.,315./            EPICS        37
                 REWIND 7                                                             MAR20         1
                 REWIND 11                                                            MAR20         2
                 REWIND 12                                                            MAR20         3
                 REWIND 14                                                            MAR20         4
                 CALL FLRCNST(RUN,IDPLOY,IOPT)                                        MAR19         8
                 READ(5,17) NFLARE                                                    EPICS        40
                 IF(NFLARE.EQ.0) GO TO 9                                              MAR20         5
              17 FORMAT(I1)                                                           MAR19         9
                 READ(5,18) (IFDIR(J),J=1,NFLARE)                                     EPICS        43
              18 FORMAT(20I1)                                                         MAR19        10
               9 READ(5,19) (MTS(J),J=1,2)                                            EPICS        45
              19 FORMAT(2A6)                                                          EPICS        46
                 CALL MSLCNST(MTS,MTP,M..,G..)                                        MAR19        11
                 CALL TGTCNST(ISNOM,TM)                                               MAR19        12
                 CALL RVSTAU(TGTALT,ISNOM)                                            EPICS        49
              11 READ(5,PARAM)                                                        MAR19        13
                 IF(IEND.NE.0) GO TO 2                                                EPICS        51
                 IF(MTP.GT.0) GO TO 3                                                 EPICS        52
                 RUN=RUN+1.                                                           EPICS        53
                 CALL INITIAL(D1,T9,MK,DF,VELT,TGTALT,IAD,ISNOM,NFO,COF,IFTYPE,MIST   EPICS        54
                +YPE,VFLARE,NG,XL,TBURN,VN,VMAX,RJDIR,T.,RUN,AM,M)                    EPICS        55
                 CALL LEAD(GL,X,XP,RXY,A4,VL,DE,V,G,T8,DLP,ALTMX,LMSF,LMSS,SUPELO,T   EPICS        56
                +HTMXD,PT)                                                            EPICS        57
                 CALL MISPAGE(X(2),RUN,MISTYPE,SSM4,L.)                               EPICS        58
```

(Table 3-2, continued)



```
      PROGRAM EPICS      74/74   OPT=1                     FTN 4.2+P380       09/01/75  13.3?.19.

                                                                              EPICS      59
      GO TO 6                                                                 EPICS      60
    8 T=T+DELT                                                                EPICS      61
      IF(T.LT.TMAX) GO TO 19                                                  EPICS      62
      WRITE(6,15)                                                             EPICS      63
   15 FORMAT(/,2X,29HMISSILE LIFESPAN EXCEEDED,/)                             EPICS      64
      GO TO 17                                                                EPICS      65
   19 N1=N1+1                                                                 MARL9      16
      CALL GYROCMD (SIG,SIGP,SI,SIP,SIGM,SIGPM,SIVA,SIPM,WLIM,ALPHA,ALPH      EPICS      67
     *AP,Z(5),ZP(5),DELT,LP,PSV,S5,T3U,T)                                     EPICS      68
      IF(L2.EQ.2) GO TO 18                                                    EPICS      69
      CALL THRUST(TL,SIG,W0,Z,ZP,ALPHA,ALPHAP,THRUST,W,T,DELT,TX,TY,TZ,G      EPICS      70
     *)                                                                       EPICS      71
      CALL COMMAND(X(5),XP(5),RT,G,W,DL,VMM,RHO,VMS,GMA,ALPM,FMACH,ALPHA      EPICS      72
     *,A,PHAP,AS,SEQ,TNT,SIND,SIPM,SETA,SIGMA,RANGE,Z(5),ZP(5),DELT,TS,R      EPICS      73
     *IAS,AX,AY,AZ,TM,T,SL)                                                   EPICS      74
      CALL [illegible](FMACH,VMM,[illegible],RHO,RI,[illegible],Z,ZP,ALPHA,ALPHAP,VMM,W,CX,CY  EPICS      75
     *,CZ)                                                                    EPICS      76
      XZ3=TX+AX+CX                                                            EPICS      77
      XZ3=TY+AY+CY                                                            EPICS      78
      XZ4=TZ+AZ+CZ-G                                                          EPICS      79
      X(2)=X(2)+XZ*DELT                                                       EPICS      80
      Y(4)=Y(4)+X6)*DELT                                                      EPICS      81
      XP(4)=XP(4)+XP4*DELT                                                    EPICS      82
      X(1)=X(1)+X(2)*DELT                                                     EPICS      83
      X(3)=X(3)+X(4)*DELT                                                     EPICS      84
      XP(3)=XP(3)+XP(4)*DELT                                                  EPICS      85
      IF(XP(3).GT.0.) GO TO 20                                                EPICS      86
      WRITE(6,21) T                                                           EPICS      87
   21 FORMAT(2X,27HMISSILE HIT GROUND AT TIME ,F9.6)                          EPICS      88
      GO TO 17                                                                EPICS      89
   20 IF(NFLARE.EQ.0) GO TO 6                                                 EPICS      90
      IF(IFOLD[illegible].EQ.1) GO TO 12                                      EPICS      91
      IF(T0.GE.T) GO TO 6                                                     MARL9      15
   12 CALL FLPCTRL  (N5,[illegible],IGT,T,TF,FTS,FTSF,STMP,CF,XFP,X,XP,TAUPN,VXF,V  EPICS      93
     *YF,VZF,[illegible],[illegible],VPPD,MEL,RF,[illegible],IDELDF,N,PI,T)   EPICS      94
      IF(M.EQ.3) GO TO 5                                                      MARL9      16
      CALL FLTDYN  (T,DELT,FF,TAUPN,SF,SFP,TF,WFD,WG,WF,[illegible],[illegible],[illegible],G,VF,V  EPICS      95
     *,VP,XFD,YF,YFP,MM,MK)                                                   MARL9      17
      CALL MFLRVEL(M,XF,YFP,XFP,YF,ZF,RELF)                                   MARL9      18
      CALL MFLANG(XF,M,ZF,PI)                                                 MARL9      19
      CALL MFLANG(VFP,M,ZFP,PI)                                               MARL9      20
      CALL FLPIR   (T,TF,RELF,M,VF,JF,HF,IDPI,ITN,JIN,FIRAND,IRNDM,PSF,P      EPICS     101
     *SFI,TAUPN,VFPDM,RNS,TAJF)                                               EPICS     102
      N1=1AP.PDI                                                              EPICS     103
      IF(N1.LT.N2) GO TO 8                                                    EPICS     104
    6 CONTINUE                                                                EPICS     105
      DO 7 K=1,M                                                              EPICS     106
      GO TO (13,13,7), MM(K)                                                  EPICS     107
   13 IF(XFP(4,K).GT.0.) GO TO 14                                             EPICS     108
      JF(K)=0.                                                                EPICS     109
      HF(K)=0.                                                                EPICS     110
      GO TO 7                                                                 EPICS     111
   14 IF(SSN2.EQ.0.) GO TO 7                                                  EPICS     112
      ZF1=ZF(1,K)*H1                                                          EPICS     113
      ZF2=ZFP(1,K)*H1                                                         EPICS     114
      ZF3=ZF(2,K)*H1                                                          EPICS     115
      ZF4=ZFP(2,K)*H1
```

(Table 3-2, concluded)

```
      PROGRAM EPICS     76/76   OPT=1                     FTN 4.2+P380       05/01/75  13.30.19.

            WRITE(6,602) K                                                    EPICS     116
        602 FORMAT(1X,7HNUMBER ,I4,1X,21H ARE CHARACTERISTICS)                EPICS     117
            WRITE(6,576) XF(5,K),XF(9,K),XP(9,K)                              EPICS     118
            WRITE(6,579) XF(7,K),YF(9,K),XP(9,K)                              EPICS     119
            WRITE(6,578) RELF(1,K),RELF(2,K),RELF(3,K)                        EPICS     120
            WRITE(6,577) RELF(7,K),RELF(8,K),VF(K)                            EPICS     121
        577 FORMAT(2X,4HREL=,F8.2,2X,5HRDREL=,F9.2,1X,3HVF=,F9.2)             EPICS     122
        578 FORMAT(2X,5HXREL=,F10.2,2X,4HYRF=,F9.2,2X,5HZREL=,F9.2)           EPICS     123
        579 FORMAT(2X,6HVXF=,F9.6,1X,6HVYF=,F9.6,2X,6HVZF=,F9.6)              EPICS     124
        576 FORMAT(2X,3HXF=,F12.7,2X,3HYF=,F10.6,2X,3HZF=,F19.6)              EPICS     125
            WRITE(6,999) SF(K),WF(K)                                          EPICS     126
        999 FORMAT(1X,3HSF=,E12.5,2X,7HWEIGHT=,F12.5)                         EPICS     127
            WRITE(6,692) JF(K),WF(K)                                          EPICS     128
        692 FORMAT(2X,10HINTENSITY=,F12.5,2X,11HIRRADIANCE=,F12.5)            EPICS     129
            WRITE(6,986) ZF1,ZF2,ZF3,ZF4                                      EPICS     130
        986 FORMAT(2X,7HSI(XY)=,F12.5,2X,7HSI(XZ)=,E12.5,2X,10HSIDOT(XY)=,F12. EPICS     131
           +6,2X,10HSIDOT(XZ)=,F12.5)                                         EPICS     132
          7 CONTINUE                                                          EPICS     133
          5 CALL TGTPH   (T,TM,DELT,AM,G,PM3,VM,VT,X(4),X(5),XP(4),X(7),X(9),X MAR20       4
           +P(9),XP7,XM9,XP97,ZTP)                                            EPICS     135
          6 VMM=SQRT(X(2)*X(2)+X(4)*X(4)+XP(6)*XP(6))                         EPICS     136
            CALL MTRVEL  (X,XP,V20,X67,XP63,XP0,XP7,XP9),T,VMM,VM9,VT,VTO,REL, MAR20       7
           +L2,TTG,RMISS,MMS1)                                                EPICS     138
            IF(L2.EQ.2) GO TO 10                                              EPICS     139
            CALL MTSTANG    (X,ALPHA,V49,C03,XM3,XP3,Z,PI)                    MAR20       8
            CALL MTSTANG    (XP,ALPHAP,XN3,XP3,XM3,XP3,ZP,PI)                 MAR20       9
            CALL TGTIR    (X(7),X(9),XP(9),WT,REL(1),REL(2),REL(3),REL(10),PI,R MAR20      10
           +INT,PANG,RN3,TAUT,AT,FIRST)                                       EPICS     143
            CALL MSLAMRT (ZF,ZFP,Z,ZP,RELF,REL,AT,AL,WF,W,HF,KT,LT,SI,SIP,SIN, MAR20      11
           +SIDP,PA,RADOT,FOV,LP,MMIN,LL,T)                                   EPICS     145
            IF(L2.EQ.2) GO TO 10                                              EPICS     146
            IF(N1.LT.N2) GO TO 5                                              EPICS     147
            N1=N                                                              MAR20      12
            IF(SSW3.NE.0.) GO TO 22                                           EPICS     149
            GO TO 23                                                          EPICS     150
         22 NN1=N-1                                                           MAR19      21
            WRITE(8) OUT,NN1,XO(3),XO(5),(XFO(8,NN),NN=1,NN1),X(3),X(5),      MAR19      22
           +(XF(8,NN),NN=1,NN1),X(1),X(4),(XF(6,NN),NN=1,NN1),ZI,Z(3),(ZF(1,NN MAR19      23
           +),NN=1,NN1),SIP,ZP(3),(ZFP(1,NN),NN=1,NN1),((IGT(NN,N1),NN=1,NN1), MAR19      24
           +N1=1,2),(JF(NN),NN=1,NN1),(RELF(7,NN),NN=1,NN1),(RELF(8,NN),NN=1,N MAR19      25
           +N1),WT,REL(10),REL(11),T                                          MAR19      26
         23 IF(T.GT.0.) GO TO 32                                              EPICS     169
            IF(SSW6.GT.0.) GO TO 32                                           EPICS     170
            CALL PAGE2(IAC,VELT,TGTALT,ITYPE,Z,ZP,SI,SIP,SID,SIDP,REL,X,XP,XP EPICS     171
           +0,XOD,XPOD,X70,X30,XP90)                                          EPICS     172
         32 CALL OUTPUT(X,XP,Z,ZP,ALPHA,ALPHAP,ZA,RADOT,SINM,SIPM,SIDM,SIDPM,X EPICS     173
           +ZD,XOD,XPOD,VT,VMM,FMACH,REL,RMISS,TTG,THRUST,W,WT,T,SSW2,TX,TY,TZ EPICS     174
           +,AX,AY,AZ,CX,CY,CZ)                                               EPICS     175
            GO TO (5,1), L2                                                   EPICS     176
          1 IF(MTP.GT.0) GO TO 3                                              EPICS     177
            GO TO 11                                                          EPICS     178
         10 TMISS=RMISS                                                       EPICS     179
            CALL CLOSAPP   (REL,TTG,DELT,RMISS,XP,T,TMAX,XM,YM,ZM,TTGT)       MAR20      13
            CALL PHCOMP(REL,Z(7),PHK,YS,XS,X4,ZS,PH)                          EPICS     181
            CALL FINPAGE(XM,YM,ZM,REL,RMISS,TMISS,TTGT,TTG,PM)                EPICS     182
            IF(SSW6.EQ.0.) GO TO 30                                           EPICS     183
            WRITE(13) RMISS,PM,TMISS,REL(13)                                  EPICS     184
            ENDFILE 13                                                        EPICS     185
         30 IF(SSW3.NE.0.) GO TO 29                                           EPICS     186
            IF(IDSPLAY.EQ.0) GO TO 11                                         EPICS     187
            ENDFILE 8                                                         EPICS     188
            WRITE(8,28) RMISS,T,PM                                            EPICS     189
         28 FORMAT(3E12.5)                                                    EPICS     190
         29 ENDFILE 8                                                         EPICS     191
            GO TO 11                                                          EPICS     192
          2 IF(SSW6.EQ.0.) GO TO 31                                           EPICS     193
            ENDFILE 13                                                        EPICS     194
            REWIND 13                                                         EPICS     195
         31 STOP                                                              EPICS     196
            END                                                               EPICS     197
```

Gyro Position and Rate Computations

Because there is a time lag associated with the gyro and the forward tracking loop, the aimpoint location, determined in subroutine aimpoint, is not tracked precisely by the missile. The actual value of $\dot{\psi}$ (aimpoint rate) which is requ:.ec to command proper acceleration, is not fed into the guidance unit of the missile until several time constants later. This effect is modeled in the program by a simple one time constant delay, which is given by:

$$\dot{\psi}_{new} = \dot{\psi}_{old} + \left(\frac{\Delta}{T_G}\right)(\dot{\psi} - \dot{\psi}_{old})$$

where,

Δ = integration step size

$\dot{\psi}_{new}$ = present gyro rate

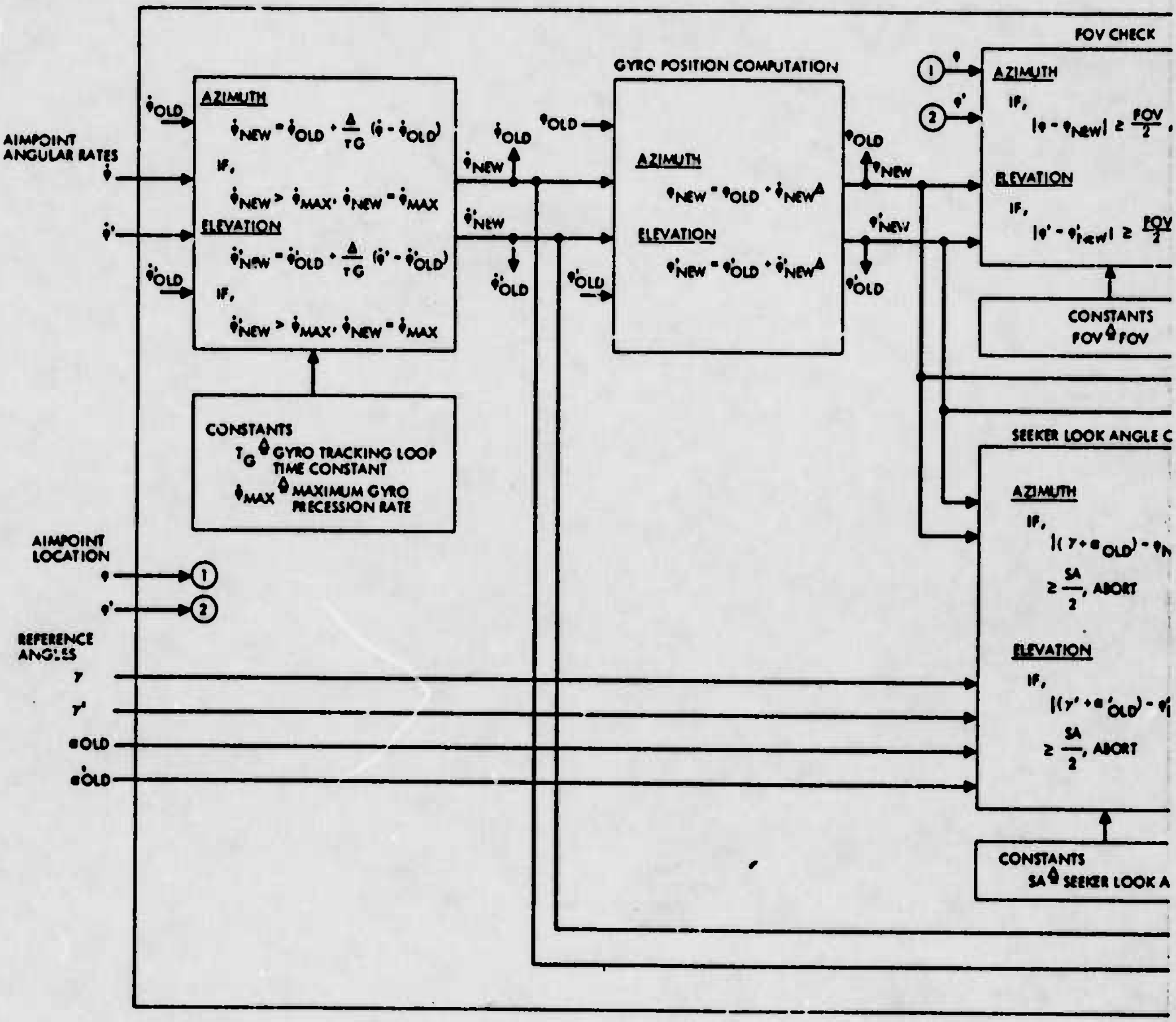
$\dot{\psi}_{old}$ = previous gyro rate

$\dot{\psi}$ = aimpoint LOS rate

T_G = time constant of the forward tracking loop

Since the simulation uses a two-plane geometry, a computation for is made for both the horizontal and vertical plane using the equation described above. If the gyro rate computed from this equation becomes greater than maximum precession rate, it is set to the maximum value. The gyro position is obtained by an integration of the rate. Figure 3-3 shows the computations performed in this subroutine.

In addition to computing gyro rate and position, this subroutine also checks the missile FOV and seeker look angle limits. If either of these limits are exceeded, the program goes into an abort mode and the point of closest approach is subsequently computed along with the probability of hit. Table 3-3 contains a listing of this subroutine.


AIMPOINT ANGULAR RATES
φ̇
φ̇'
φ̇OLD
φ̇'OLD
AZIMUTH
φ̇NEW = φ̇OLD + Δ/τG (φ̇ - φ̇OLD)
IF,
φ̇NEW > φ̇MAX, φ̇NEW = φ̇MAX
ELEVATION
φ̇'NEW = φ̇'OLD + Δ/τG (φ̇' - φ̇'OLD)
IF,
φ̇'NEW > φ̇MAX, φ̇'NEW = φ̇MAX
CONSTANTS
τG ≙ GYRO TRACKING LOOP TIME CONSTANT
φ̇MAX ≙ MAXIMUM GYRO PRECESSION RATE
φ̇NEW
φ̇OLD
φ̇'NEW
φ̇'OLD
GYRO POSITION COMPUTATION
φOLD
φ'OLD
AZIMUTH
φNEW = φOLD + φ̇NEWΔ
ELEVATION
φ'NEW = φ'OLD + φ̇'NEWΔ
φOLD
φNEW
φ'NEW
φ'OLD
FOV CHECK
φ
φ'
AZIMUTH
IF,
|φ - φNEW| ≥ FOV/2
ELEVATION
IF,
|φ' - φ'NEW| ≥ FOV/2
CONSTANTS
FOV ≙ FOV
SEEKER LOOK ANGLE C
AZIMUTH
IF,
|(γ + αOLD) - φN
≥ SA/2, ABORT
ELEVATION
IF,
|(γ' + α'OLD) - φ'
≥ SA/2, ABORT
CONSTANTS
SA ≙ SEEKER LOOK A
AIMPOINT LOCATION
φ
φ'
1
2
REFERENCE ANGLES
γ
γ'
αOLD
α'OLD

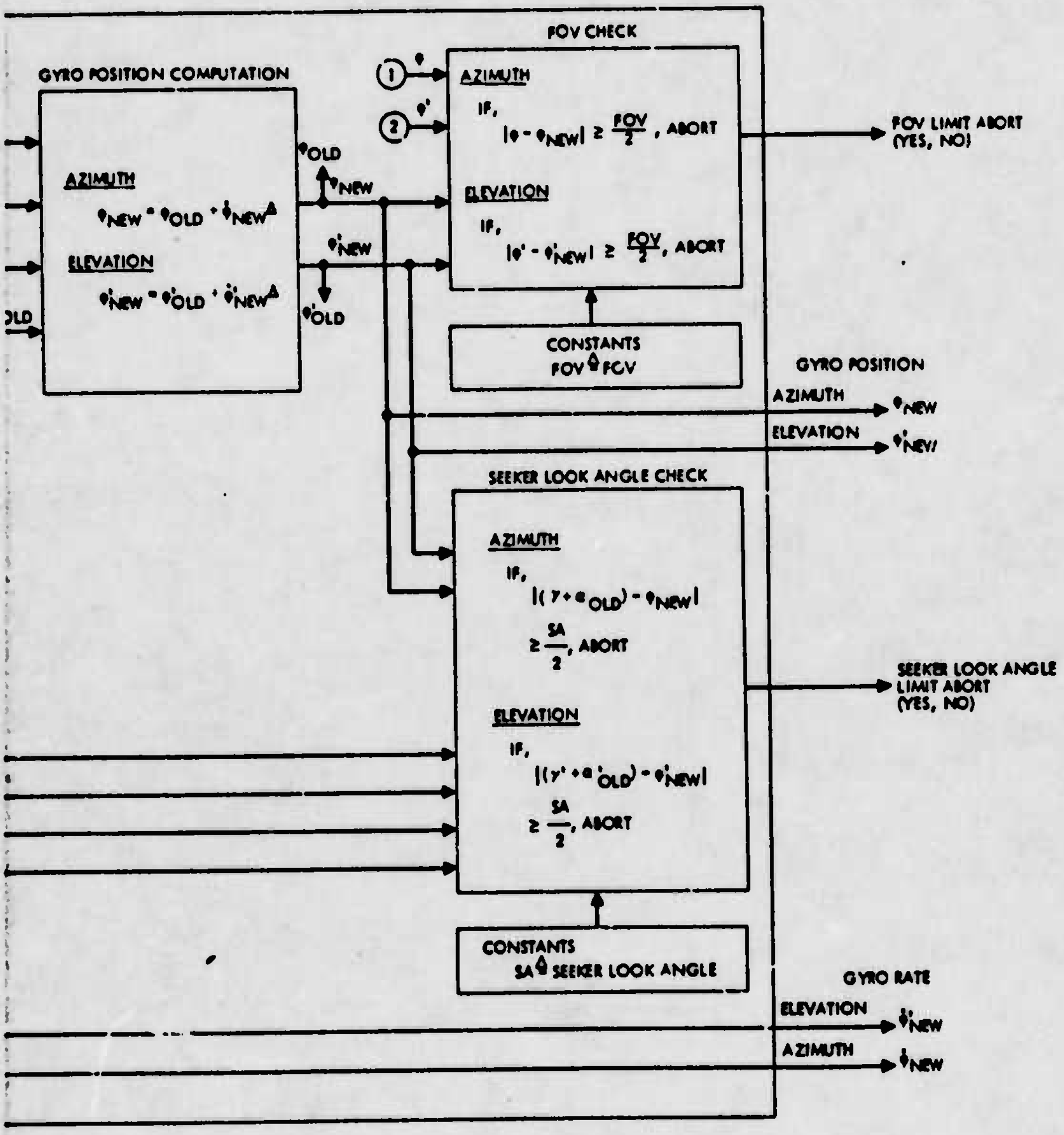

GYRO POSITION COMPUTATION
AZIMUTH
$\phi_{NEW} = \phi_{OLD} + \dot{\phi}_{NEW}\Delta$
ELEVATION
$\phi'_{NEW} = \phi'_{OLD} + \dot{\phi}'_{NEW}\Delta$
OLD
ϕ_{OLD}
ϕ_{NEW}
ϕ'_{NEW}
ϕ'_{OLD}
FOV CHECK
1
2
ϕ
ϕ'
AZIMUTH
IF,
$|\phi - \phi_{NEW}| \geq \frac{FOV}{2}$, ABORT
ELEVATION
IF,
$|\phi' - \phi'_{NEW}| \geq \frac{FOV}{2}$, ABORT
CONSTANTS
FOV $\triangleq$ FOV
FOV LIMIT ABORT
(YES, NO)
GYRO POSITION
AZIMUTH
ϕ_{NEW}
ELEVATION
ϕ'_{NEW}
SEEKER LOOK ANGLE CHECK
AZIMUTH
IF,
$|(\gamma + \alpha_{OLD}) - \phi_{NEW}|$
$\geq \frac{SA}{2}$, ABORT
ELEVATION
IF,
$|(\gamma' + \alpha'_{OLD}) - \phi'_{NEW}|$
$\geq \frac{SA}{2}$, ABORT
CONSTANTS
SA $\triangleq$ SEEKER LOOK ANGLE
SEEKER LOOK ANGLE
LIMIT ABORT
(YES, NO)
GYRO RATE
ELEVATION
$\dot{\phi}'_{NEW}$
AZIMUTH
$\dot{\phi}_{NEW}$

Figure 3-3. Gyro position and rate computations

2

Table 3-3. Gyro position and rate computation subroutine

```
SUBROUTINE GYROCMP     74/74    OPT=1                      FTN 4.2+P380       05/01/75  13.30.47.

                SUBROUTINE GYROCMP(SIO,SIOP,SI,SIP,SION,SIOPN,SIN,SIPN,SIOMAX,ALP  MAR19       38
               *HA,ALPHAP,GAM,GAMP,DELT,L2,FOV,SA,TGU,T)                            GYROCOMP     3
                IF(T.GT.DELT) GO TO 7                                               GYROCOMP     4
                SION=SIO                                                            GYROCOMP     5
                SIOPN=SIOP                                                          GYROCOMP     6
                SIN=SI                                                              GYROCOMP     7
                SIPN=SIP                                                            GYROCOMP     8
              7 SION=SION+DELT/TGU*(SIO-SION)                                       GYROCOMP     9
                IF(SION.LE.SIOMAX) GO TO 1                                          GYROCOMP    10
                SION=SIGN(SIOMAX,SION)                                              GYROCOMP    11
              1 SIOPN=SIOPN+DELT/TGU*(SIOP-SIOPN)                                   GYROCOMP    12
                IF(SIOPN.LE.SIOMAX) GO TO 2                                         GYROCOMP    13
                SIOPN=SIGN(SIOMAX,SIOPN)                                            GYROCOMP    14
              2 SIN=SIN+SIPN*DELT                                                   GYROCOMP    15
                SIPN=SIPN+SIOPN*DELT                                                GYROCOMP    16
                IF(ABS(SI-SIN).LT.FOV/2.) GO TO 3                                   GYROCOMP    17
                WRITE(6,8)                                                          MAR19       39
              8 FORMAT(1X,10HABORT COND)                                            MAR19       40
                WRITE(6,9) SI,SIN,FOV                                               MAR19       41
              9 FORMAT(1X,3HSI=,E12.6,1X,4HSIN=,E12.6,1X,4HFOV=,E12.6)              MAR19       42
                L2=2                                                                GYROCOMP    20
                RETURN                                                              GYROCOMP    21
              3 IF(ABS(SIP-SIPN).LT.FOV/2.) GO TO 4                                 GYROCOMP    22
                WRITE(6,8)                                                          MAR19       43
                WRITE(6,10) SIP,SIPN,FOV                                            MAR19       44
                L2=2                                                                GYROCOMP    25
                RETURN                                                              GYROCOMP    26
              4 IF(ABS(GAM+ALPHA-SIN).LT.SA/2.) GO TO 5                             GYROCOMP    27
                WRITE(6,8)                                                          MAR19       45
                WRITE(6,11) GAM,ALPHA,SIN,SA                                        MAR19       46
                L2=2                                                                GYROCOMP    30
                RETURN                                                              GYROCOMP    31
              5 IF(ABS(GAMP+ALPHAP-SIPN).LT.SA/2.) GO TO 6                          GYROCOMP    32
                WRITE(6,8)                                                          MAR19       47
                WRITE(6,12) GAMP,ALPHAP,SIPN,SA                                     MAR19       48
             10 FORMAT(1X,4HSIP=,E12.6,1X,5HSIPN=,E12.6,1X,4HFOV=,E12.6)            MAR19       49
             11 FORMAT(1X,4HGAM=,E12.6,1X,6HALPHA=,E12.6,1X,4HSIN=,E12.6,1X,3HSA=,  MAR19       50
               *E12.6)                                                              MAR19       51
             12 FORMAT(1X,5HGAMP=,E12.6,1X,7HALPHAP=,E12.6,1X,5HSIPN=,E12.6,1X,3HS  MAR19       52
               *A=,E12.6)                                                           MAR19       53
                L2=2                                                                GYROCOMP    35
              6 RETURN                                                              GYROCOMP    36
                END                                                                 GYROCOMP    37
```

Thrust

The propulsion system of a missile is completely defined by thrust-time history, specific impulse (delivered) and motor weight drop (if applicable) data. Figure 3-4 shows the computations performed in subroutine thrust and Table 3-4 contains a listing of this subroutine.

The thrust-time, motor weight drop-time, and specific impulse-time, profiles are stored tables in the program which are read in as part of the missile file data. The values of these variables are then found by means of a table lookup.

It is necessary to formulate this force into its X-, Y-, and Z-acceleration components. Table 3-5 shows the computational procedure for performing this operation and Figure 3-4 shows the equations used in implementing this component resolution, with the (G/W_{new}) factor accounting for the conversion of force to acceleration.

The thrust subroutine in addition to computing the thrust components also computes the missile weight. The change in missile weight during the thrust period is given by:

$$W_{new} = W_{old} - (\text{thrust}/S)\,\Delta - W_o$$

where

W_{new} = new missile weight

W_{old} = old missile weight

Δ = integration step size

S = specific impulse

W_o = motor weight drop at end of boost period (if applicable)

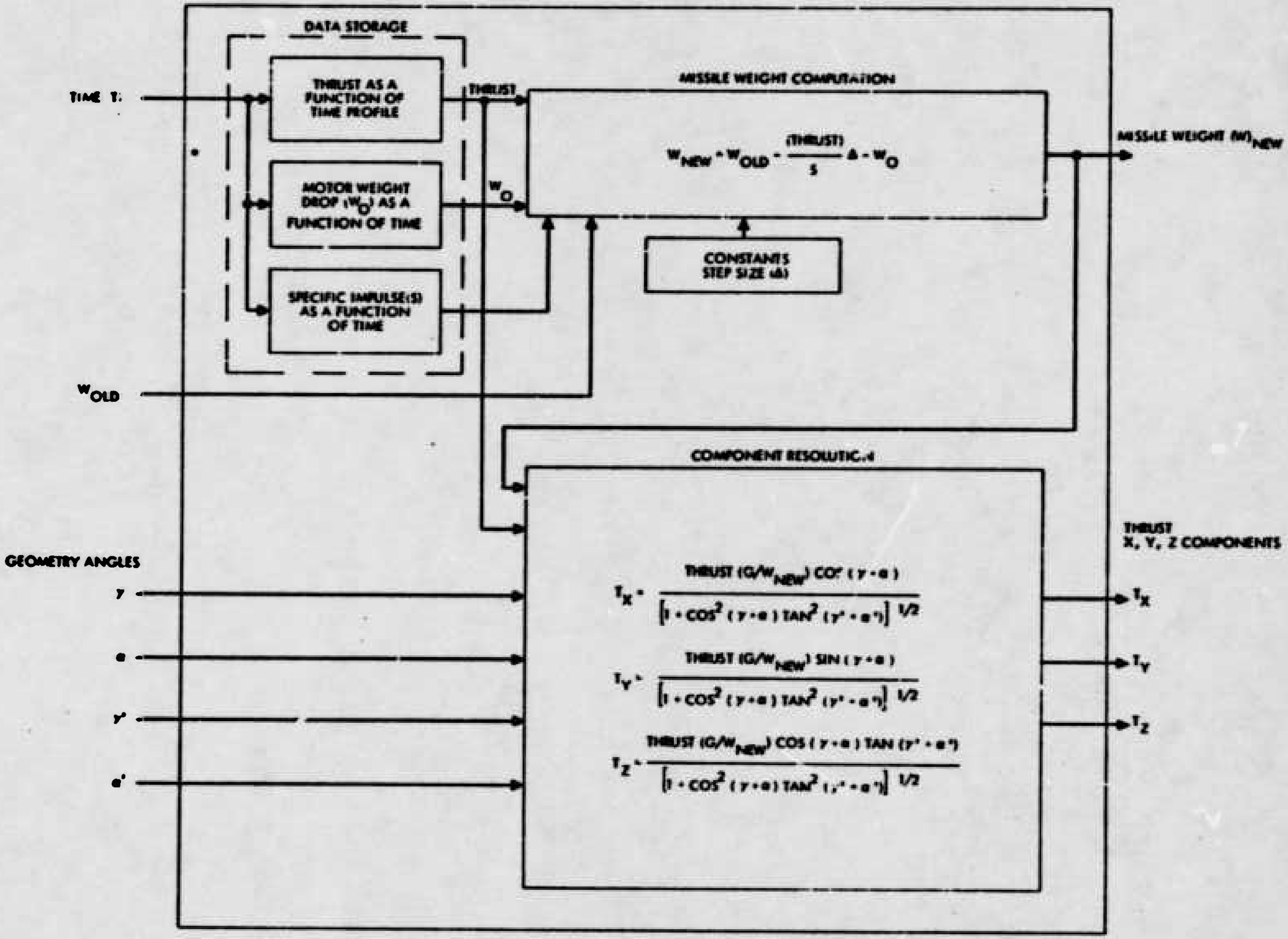
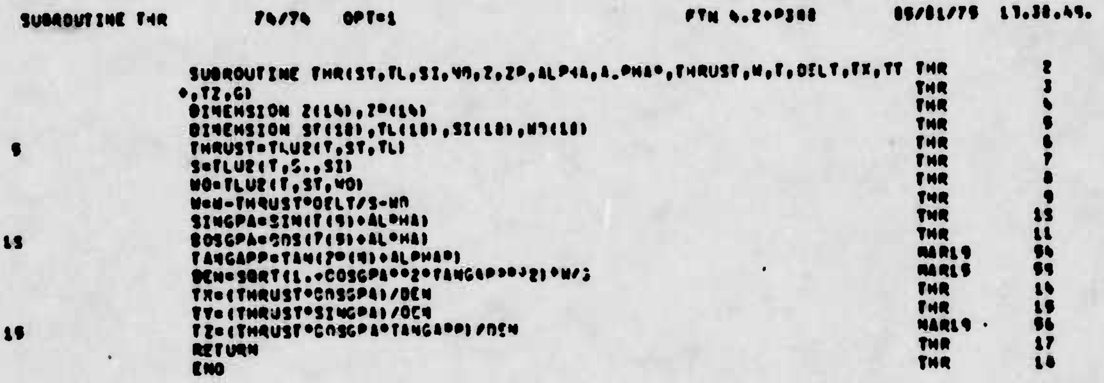

DATA STORAGE
TIME T:
THRUST AS A FUNCTION OF TIME PROFILE
MOTOR WEIGHT DROP (W_O) AS A FUNCTION OF TIME
SPECIFIC IMPULSE(S) AS A FUNCTION OF TIME
THRUST
W_O
W_{OLD}
MISSILE WEIGHT COMPUTATION
$W_{NEW} = W_{OLD} - \frac{(THRUST)}{S} \Delta - W_O$
CONSTANTS STEP SIZE (Δ)
MISSILE WEIGHT (W)$_{NEW}$
COMPONENT RESOLUTION
GEOMETRY ANGLES
γ
ε
γ'
ε'
$T_X = \frac{THRUST\ (G/W_{NEW})\ COS\ (\gamma + \varepsilon)}{[1 + COS^2\ (\gamma + \varepsilon)\ TAN^2\ (\gamma' + \varepsilon')]^{1/2}}$
$T_Y = \frac{THRUST\ (G/W_{NEW})\ SIN\ (\gamma + \varepsilon)}{[1 + COS^2\ (\gamma + \varepsilon)\ TAN^2\ (\gamma' + \varepsilon')]^{1/2}}$
$T_Z = \frac{THRUST\ (G/W_{NEW})\ COS\ (\gamma + \varepsilon)\ TAN\ (\gamma' + \varepsilon')}{[1 + COS^2\ (\gamma + \varepsilon)\ TAN^2\ (\gamma' + \varepsilon')]^{1/2}}$
THRUST X, Y, Z COMPONENTS
T_X
T_Y
T_Z

Figure 3-4. Thrust computations

Table 3-4. Thrust subroutine



```
SUBROUTINE THR        74/74   OPT=1                    FTN 4.2+P380          08/01/75  13.38.49.

              SUBROUTINE THR(ST,TL,SI,WO,Z,ZP,ALPHA,ALPHAP,THRUST,W,T,DELT,TX,TY THR          2
             +,TZ,G)                                                           THR          3
              DIMENSION Z(10),ZP(10)                                           THR          4
              DIMENSION ST(10),TL(10),SI(10),WO(10)                            THR          5
              THRUST=TLU2(T,ST,TL)                                             THR          6
              S=TLU2(T,ST,SI)                                                  THR          7
              WO=TLU2(T,ST,WO)                                                 THR          8
              W=W-THRUST*DELT/S-WO                                             THR          9
              SINGPA=SIN(Z(5)+ALPHA)                                           THR         10
              COSGPA=COS(Z(5)+ALPHA)                                           THR         11
              TANGAPP=TAN(ZP(5)+ALPHAP)                                        MARL9       94
              DEN=SQRT(1.+COSGPA**2*TANGAPP**2)*W/G                            MARL9       95
              TX=(THRUST*COSGPA)/DEN                                           THR         14
              TY=(THRUST*SINGPA)/DEN                                           THR         15
              TZ=(THRUST*COSGPA*TANGAPP)/DEN                                   MARL9       96
              RETURN                                                           THR         17
              END                                                              THR         18
```

Table 3-5. Thrust vector components

From geometry,

$$T_x = T_{xy} * \cos(\gamma + \alpha) = T_{xz} * \cos(\gamma' + \alpha') \quad .$$

$$T_{xz} = T_{xy} * \cos(\gamma + \alpha)/\cos(\gamma' + \alpha')$$

Now,

$$T^2 = T_x{}^2 + T_y{}^2 + T_z{}^2$$

$$= T_{xy}{}^2 * \cos^2(\gamma + \alpha) + T_{xy}{}^2 * \sin^2(\gamma + \alpha) + T_{xz}{}^2 * \sin^2(\gamma' + \alpha')$$

$$= T_{xy}{}^2 + T_{xz}{}^2 * \sin^2(\gamma' + \alpha')$$

$$= T_{xy}{}^2 + T_{xy}{}^2 * \sin^2(\gamma' + \alpha') * \cos^2(\gamma + \alpha)/\cos^2(\gamma' + \alpha')$$

$$T_{xy} = \frac{T}{\left[1 + \cos^2(\gamma + \alpha) * \tan^2(\gamma' + \alpha')\right]^{1/2}}$$

$$T_{xz} = \frac{T * \cos(\gamma + \alpha)/\cos(\gamma' + \alpha')}{\left[1 + \cos^2(\gamma + \alpha) * \tan^2(\gamma' + \alpha')\right]^{1/2}}$$

$$\boxed{\begin{aligned} T_x &= \frac{T * \cos(\gamma + \alpha)}{\left[1 + \cos^2(\gamma + \alpha) * \tan^2(\gamma' + \alpha')\right]^{1/2}} \\ T_y &= \frac{T * \sin(\gamma + \alpha)}{\left[1 + \cos^2(\gamma + \alpha) * \tan^2(\gamma' + \alpha')\right]^{1/2}} \\ T_z &= \frac{T * \cos(\gamma + \alpha) * \tan(\gamma' + \alpha')}{\left[1 + \cos^2(\gamma + \alpha) * \tan^2(\gamma + \alpha')\right]^{1/2}} \end{aligned}}$$

Chord

The magnitude of chord force is given by the expression

$$1/2\ \rho C_c \pi(D_M/2)^2 V^2$$

where

ρ = atmospheric density

C_c = chord force coefficient (a function of mach number)

$\pi(D_M/2)^2$ = missile cross-sectional area

V = missile velocity

The atmospheric density (ρ) is modeled as an exponential function of altitude and computed only once in subroutine initial.

The chord force coefficient is a function of mach number and is found in the program by means of a table lookup.

The missile velocity needed to calculate the chord force is computed in the range and range rate computation subroutine.

The chord force is directed opposite the thrust vector and therefore has the same X-, Y-, and Z-unit vector components as the thrust vector.

Figure 3-5 shows the overall computations of subroutine thrust and Table 3-6 contains a listing of this subroutine.

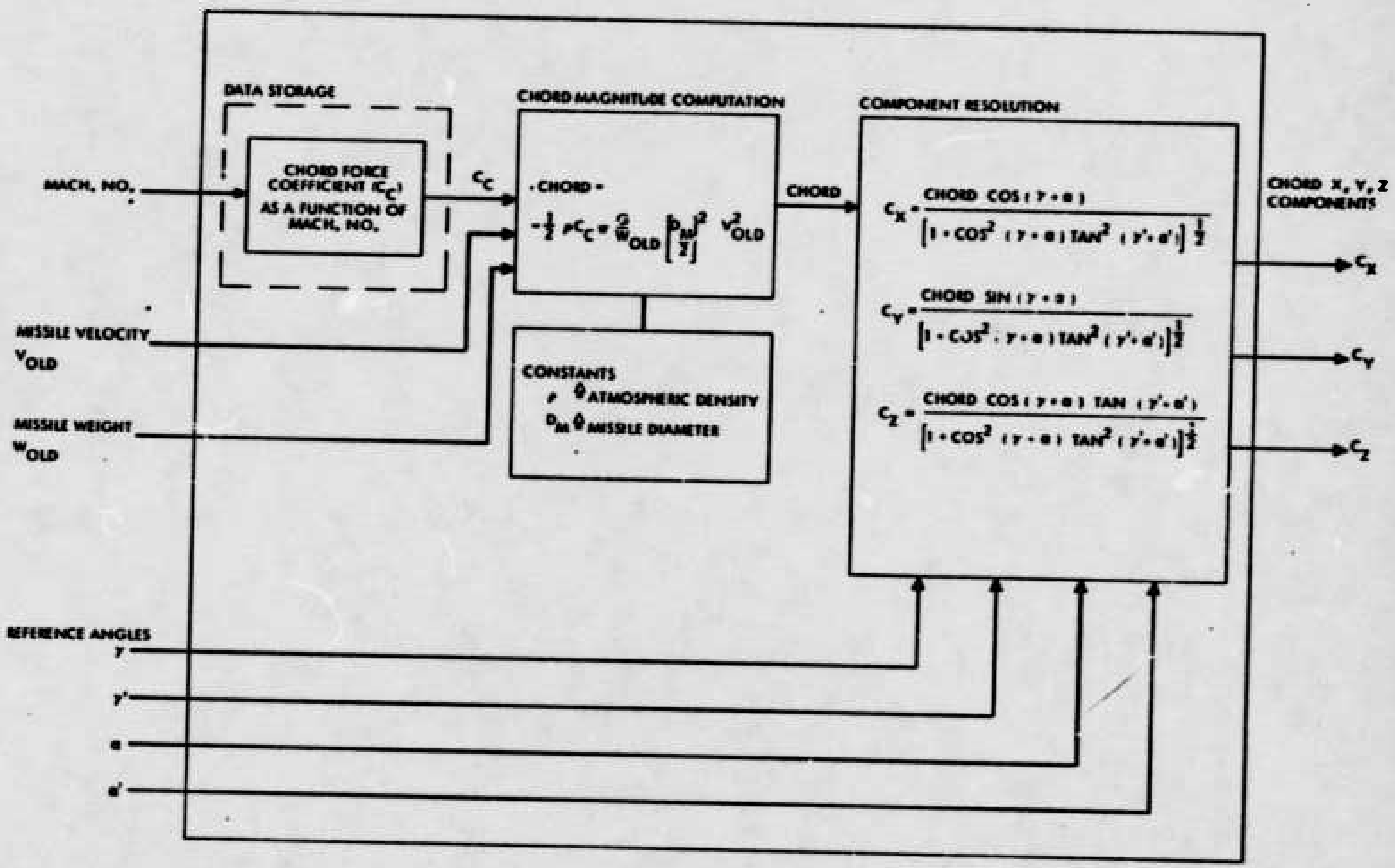

DATA STORAGE
CHORD FORCE COEFFICIENT (C_C) AS A FUNCTION OF MACH. NO.
MACH. NO.
MISSILE VELOCITY V_{OLD}
MISSILE WEIGHT W_{OLD}
C_C
CHORD MAGNITUDE COMPUTATION
$\cdot$CHORD $=$
$-\frac{1}{2}\rho C_C = \frac{g}{W_{OLD}}\left[\frac{D_M}{2}\right]^2 V^2_{OLD}$
CONSTANTS
ρ ≙ ATMOSPHERIC DENSITY
D_M ≙ MISSILE DIAMETER
CHORD
COMPONENT RESOLUTION
$C_X = \frac{\text{CHORD COS}(\gamma+\theta)}{\left[1+\text{COS}^2(\gamma+\theta)\,\text{TAN}^2(\gamma'+\theta')\right]^{\frac{1}{2}}}$
$C_Y = \frac{\text{CHORD SIN}(\gamma+\theta)}{\left[1+\text{CJS}^2(\gamma+\theta)\,\text{TAN}^2(\gamma'+\theta')\right]^{\frac{1}{2}}}$
$C_Z = \frac{\text{CHORD COS}(\gamma+\theta)\,\text{TAN}(\gamma'+\theta')}{\left[1+\text{COS}^2(\gamma+\theta)\,\text{TAN}^2(\gamma'+\theta')\right]^{\frac{1}{2}}}$
CHORD X, Y, Z COMPONENTS
C_X
C_Y
C_Z
REFERENCE ANGLES
γ
γ'
θ
θ'

Figure 3-5. Chord acceleration computations

Table 3-6. Chord subroutine

```
                                                                  FTN 4.2+P398      05/01/78  13.30.55.
SUBROUTINE CHORD       74/74   OPT=1

              SUBROUTINE CHORD(FMACH,VMC,COD,R40,PI,G,D1,Z,ZP,ALPHA,ALPHAP,VM,M, CHORD        2
                                                                                 CHORD        3
             +CX,CY,CZ)                                                          CHORD        4
              DIMENSION VMC(8),COD(8),Z(16),ZP(16)                               CHORD        5
              VMN=VM/FMACH                                                       CHORD        6
              CC=TLU2(VMN,VMC,COD)                                               CHORD        7
              DIA=D1/12.                                                         CHORD        8
              CORD=-(.5*RHO*CC*PI*G/M)*(DIA*DIA)/6.*(VM*VM)                      CHORD        9
              COSGPA=COS(Z(9)+ALPHA)                                             CHORD       16
              SINGPA=SIN(Z(9)+ALPHA)                                             MAR19       57
              TANGAPP=TAN(ZP(9)+ALPHAP)                                          MAR19       58
              DEN=SQRT(1.+COSGPA**2*TANGAPP**2)                                  CHORD       13
              CX=(CORD*COSGPA)/DEN                                               CHORD       14
              CY=(CORD*SINGPA)/DEN                                               MAR20       17
              CZ=(CORD*COSGPA*TANGAPP)/DEN                                       CHORD       15
              RETURN                                                             CHORD       17
              END
```

Commanded Acceleration

Commanded Force

The commanded force results from the horizontal and vertical guidance commands generated in the missile. The commanded force is based on a proportional navigation system with navigation parameter. It is assumed that the missile has its control surfaces or flippers biased to account for any lift force and tc fly straight and level during normal flight conditions. The commanded acceleration in the vertical and horizontal plane is given by the expression:

$$X_n = -\frac{\Lambda \dot{r}_{xy} \dot{\psi}_{new}}{\cos(\gamma - \psi_{new} + \alpha)} \qquad \text{(horizontal)}$$

$$X_n' = \frac{\Lambda \dot{r}_{XZ} \dot{\psi}'_{new}}{\cos(\gamma' - \psi'_{new} + \alpha')} + G{*}BIAS \qquad \text{(vertical)}$$

where,

Λ = navigation parameter

ψ_{new}, ψ'_{new} = gyro rates - horizontal and vertical

ψ_{new}, ψ'_{new} = gyro position - horizontal and vertical

α, α' = angle of attack - horizontal and vertical

γ, γ' = missile body angles - horizontal and vertical

$\dot{r}_{XY}, \dot{r}_{XZ}$ = aimpoint range rates - horizontal and vertical

BIAS = gravity bias term

The derivation of this guidance law is given in the following subsection.

To account for gravity bias missile systems, i.e., missiles which have their horizontal control surfaces biased in such a manner as to effectively null out gravity, the vertical commanded acceleration includes a gravity bias term, G*BIAS.

BIAS is the variable which controls the amount of gravity bias the missile is to have.

To compute the commanded acceleration, it is necessary to determine $\dot{r}_{XY}$ and $\dot{r}_{XZ}$ in terms of $\dot{r}$ (the closing rate along the LOS). Table 3-7 shows this computation.

Figure 3-6 shows the commanded acceleration computation and also shows that commanded acceleration is aerodynamically and structurally limited.

The commanded force is limited aerodynamically to be less than the maximum lift force given in the same table to be $1/2*p*C_{NMAX}*\pi*(D_M/2)^2*V^2$ C_{NMAX} is a function of mach number as incidated in the figure.

A limit is set in the missile's autopilot or guidance unit to prevent over-maneuvering against the target. This is a g-limit and is designed by the term A5 in the program.

The g-limit is a limit internal to the missile whereas the aerodynamic limit isan external limit. At any given time and for any given missile, only one or the other constraint will be dominant. These two limits represent constraints on commanded acceleration X(5), XP(5)) and are also the only state constraints in the program.

The missile does not respond instantaneously to the commanded force. There is a delay associated with time for target information to go through the signal processor and guidance unit and finally to reach the control surface actuators. This delay is also modeled as a one time constant delay. The resulting equations are:

$$X(5)_{new} = X(5)_{old} + \frac{\Delta}{T_S}(G1 - X(5)_{old})$$

$$XP(5)_{new} = XP(5)_{old} + \frac{\Delta}{T_S}(G1' - XP(5)_{old})$$

Table 3-7. Range rate vector components

From geometry,

$$\dot{r}_x = \dot{r}_{xy} * \cos(\psi) = \dot{r}_{xz} * \cos(\psi')$$

$$\dot{r}_{xz} = \dot{r}_{xy} * \cos(\psi)/\cos(\psi')$$

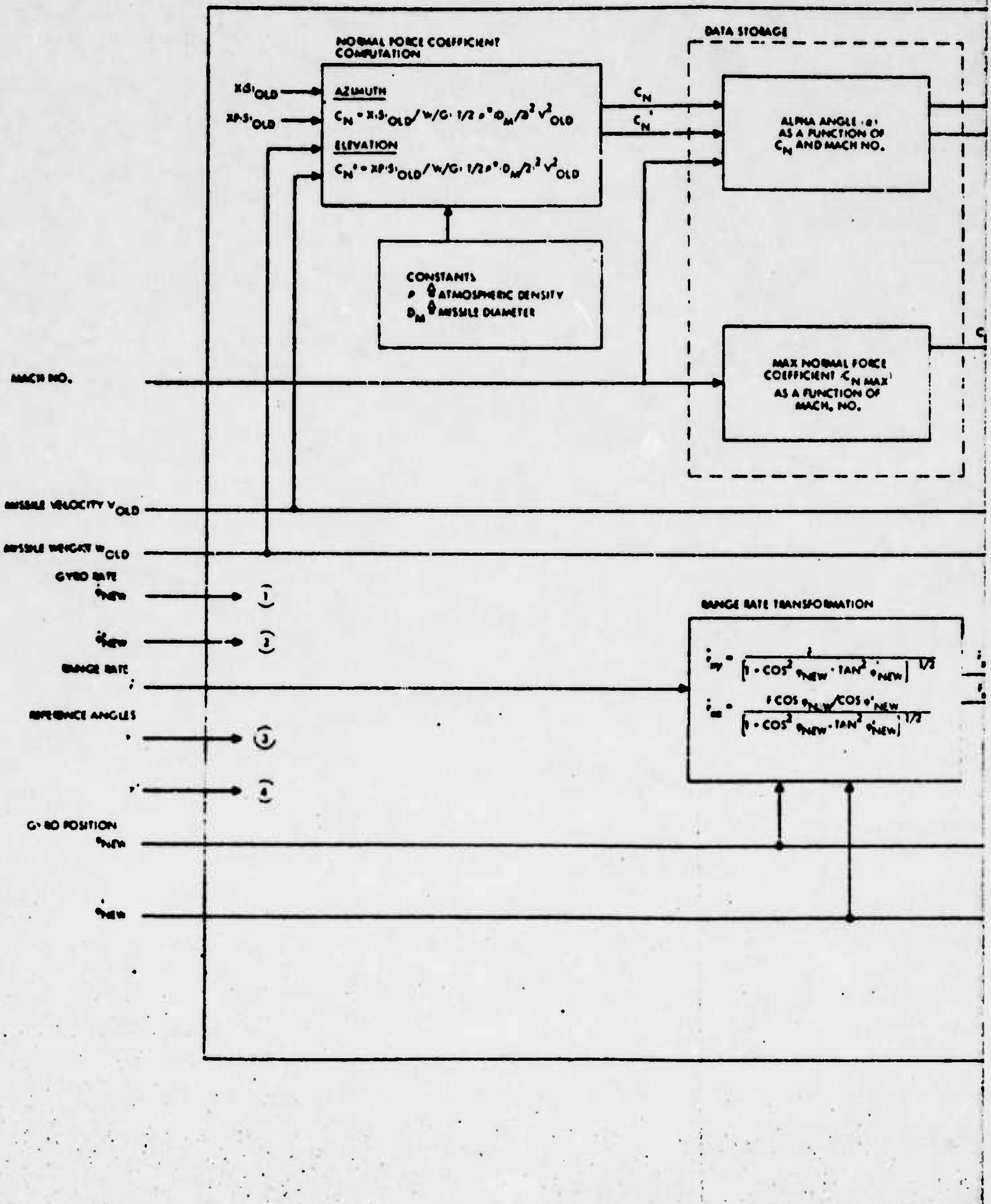
Now,

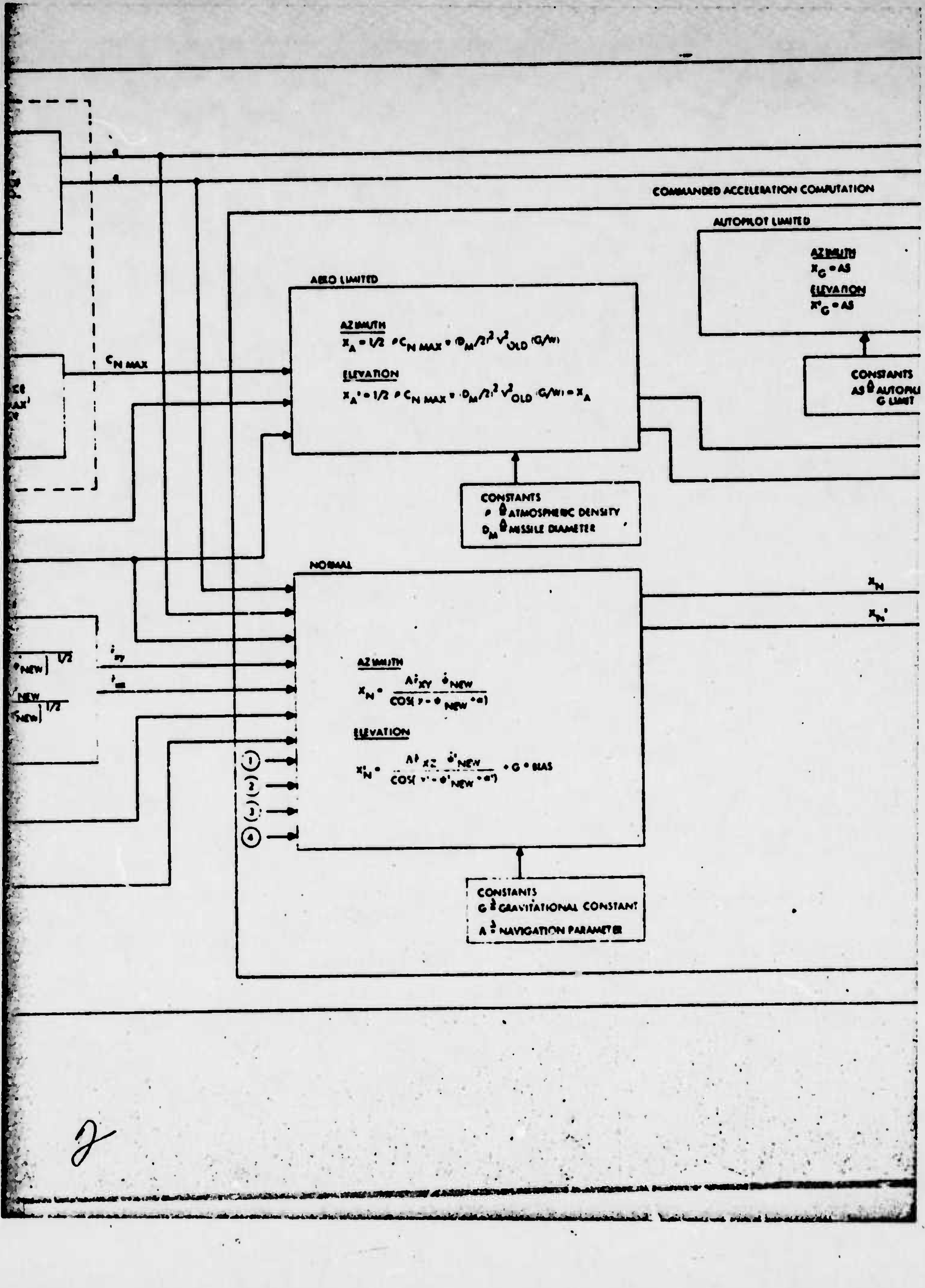
$$\begin{aligned}
\dot{r}^2 &= \dot{r}_x{}^2 + \dot{r}_y{}^2 + \dot{r}_z{}^2 \\
&= \dot{r}_{xy}{}^2 * \cos^2(\psi) + \dot{r}_{xy}{}^2 * \sin^2(\psi) + \dot{r}_{xz}{}^2 * \sin^2(\psi') \\
&= \dot{r}_{xy}{}^2 + \dot{r}_{xz}{}^2 * \sin^2(\psi') \\
&= \dot{r}_{xy}{}^2 + \dot{r}_{xy}{}^2 * \sin^2(\psi') * \cos^2(\psi)/\cos^2(\psi')
\end{aligned}$$

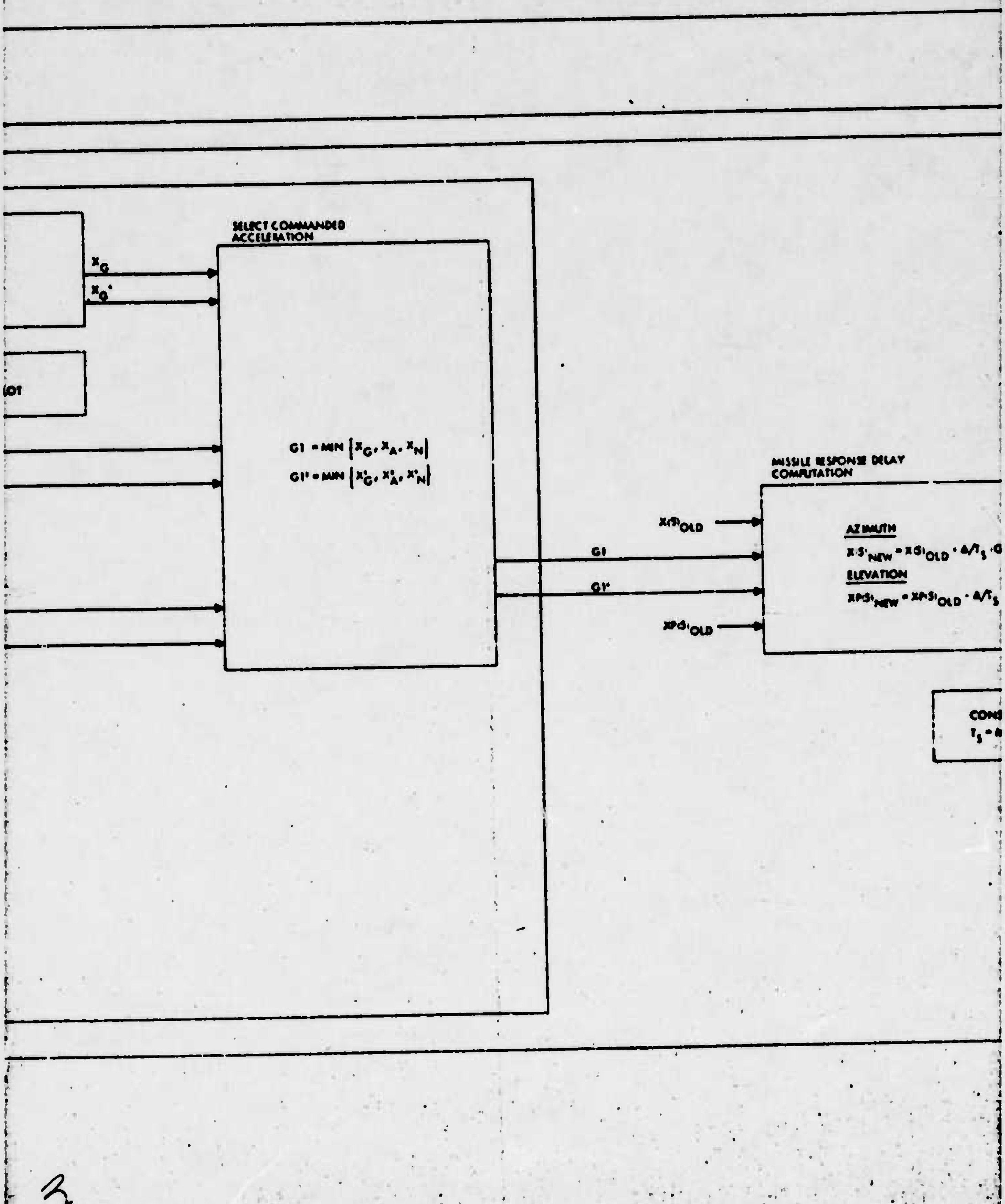
$$\dot{r}_{xy} = \frac{\dot{r}}{\left[1 + \cos^2(\psi) * \tan^2(\psi')\right]^{1/2}}$$

$$\dot{r}_{xz} = \frac{\dot{r} * \cos(\psi)/\cos(\psi')}{\left[1 + \cos^2(\psi) * \tan^2(\psi')\right]^{1/2}}$$

$$\boxed{\begin{aligned}
\dot{r}_x &= \frac{\dot{r} * \cos(\psi)}{\left[1 + \cos^2(\psi) * \tan^2(\psi')\right]^{1/2}} \\
\dot{r}_y &= \frac{\dot{r} * \sin(\psi)}{\left[1 + \cos^2(\psi) * \tan^2(\psi')\right]^{1/2}} \\
\dot{r}_z &= \frac{\dot{r} * \cos(\psi) * \tan(\psi')}{\left[1 + \cos^2(\psi) * \tan^2(\psi')\right]^{1/2}}
\end{aligned}}$$


NORMAL FORCE COEFFICIENT COMPUTATION
XS'_{OLD}
$XP\cdot S'_{OLD}$
AZIMUTH
$C_N = X\cdot S'_{OLD}/W/G \cdot 1/2\,\rho \cdot \pi D_M/2^2\,V^2_{OLD}$
ELEVATION
$C_N' = XP\cdot S'_{OLD}/W/G \cdot 1/2\,\rho \cdot \pi D_M/2^2\,V^2_{OLD}$
CONSTANTS
$\rho \triangleq$ ATMOSPHERIC DENSITY
$D_M \triangleq$ MISSILE DIAMETER
C_N
C_N'
DATA STORAGE
ALPHA ANGLE (α) AS A FUNCTION OF C_N AND MACH NO.
MAX NORMAL FORCE COEFFICIENT ($C_{N\,MAX}$) AS A FUNCTION OF MACH. NO.
MACH NO.
MISSILE VELOCITY V_{OLD}
MISSILE WEIGHT W_{OLD}
GYRO RATE
$\dot{\theta}_{NEW}$
$\dot{\psi}_{NEW}$
1
2
RANGE RATE
$\dot{r}$
REFERENCE ANGLES
3
4
GYRO POSITION
θ_{NEW}
ψ_{NEW}
RANGE RATE TRANSFORMATION
$\dot{r}_{my} = \dfrac{\dot{r}}{[1 + \cos^2\theta_{NEW}\cdot\tan^2\psi_{NEW}]^{1/2}}$
$\dot{r}_{mz} = \dfrac{\dot{r}\cos\theta_{NEW}/\cos\psi'_{NEW}}{[1 + \cos^2\theta_{NEW}\cdot\tan^2\psi_{NEW}]^{1/2}}$


COMMANDED ACCELERATION COMPUTATION
AUTOPILOT LIMITED
AZIMUTH
$X_G = AS$
ELEVATION
$X'_G = AS$
CONSTANTS
AS ≜ AUTOPIL
G LIMIT
AERO LIMITED
AZIMUTH
$X_A = 1/2\ \rho C_{N\ MAX} \cdot (D_M/2)^2 V^2_{OLD}\ (G/W)$
ELEVATION
$X_A' = 1/2\ \rho C_{N\ MAX} \cdot (D_M/2)^2 V^2_{OLD}\ (G/W) = X_A$
CONSTANTS
ρ ≜ ATMOSPHERIC DENSITY
D_M ≜ MISSILE DIAMETER
$C_{N\ MAX}$
NORMAL
AZIMUTH
$X_N = \frac{A \dot{r}_{XY}\ \dot{\phi}_{NEW}}{\cos(\gamma - \phi_{NEW} + \alpha)}$
ELEVATION
$X'_N = \frac{A \dot{r}_{XZ}\ \dot{\phi}'_{NEW}}{\cos(\gamma' - \phi'_{NEW} + \alpha')} + G + BIAS$
CONSTANTS
G ≜ GRAVITATIONAL CONSTANT
A ≜ NAVIGATION PARAMETER
X_N
X_N'
$\dot{r}_{XY}$
$\dot{r}_{XZ}$
1
2
3
4
CE
AX'
NEW] 1/2
NEW
NEW] 1/2


x_G
x_G'
IOT
SELECT COMMANDED ACCELERATION
G1 = MIN |x_G, x_A, x_N|
G1' = MIN |x'_G, x'_A, x'_N|
G1
G1'
MISSILE RESPONSE DELAY COMPUTATION
X(S)OLD
XPSIOLD
AZIMUTH
XS'NEW = XSIOLD + Δ/TS ·G
ELEVATION
XPSI'NEW = XPSIOLD + Δ/TS
CONS
TS =

3

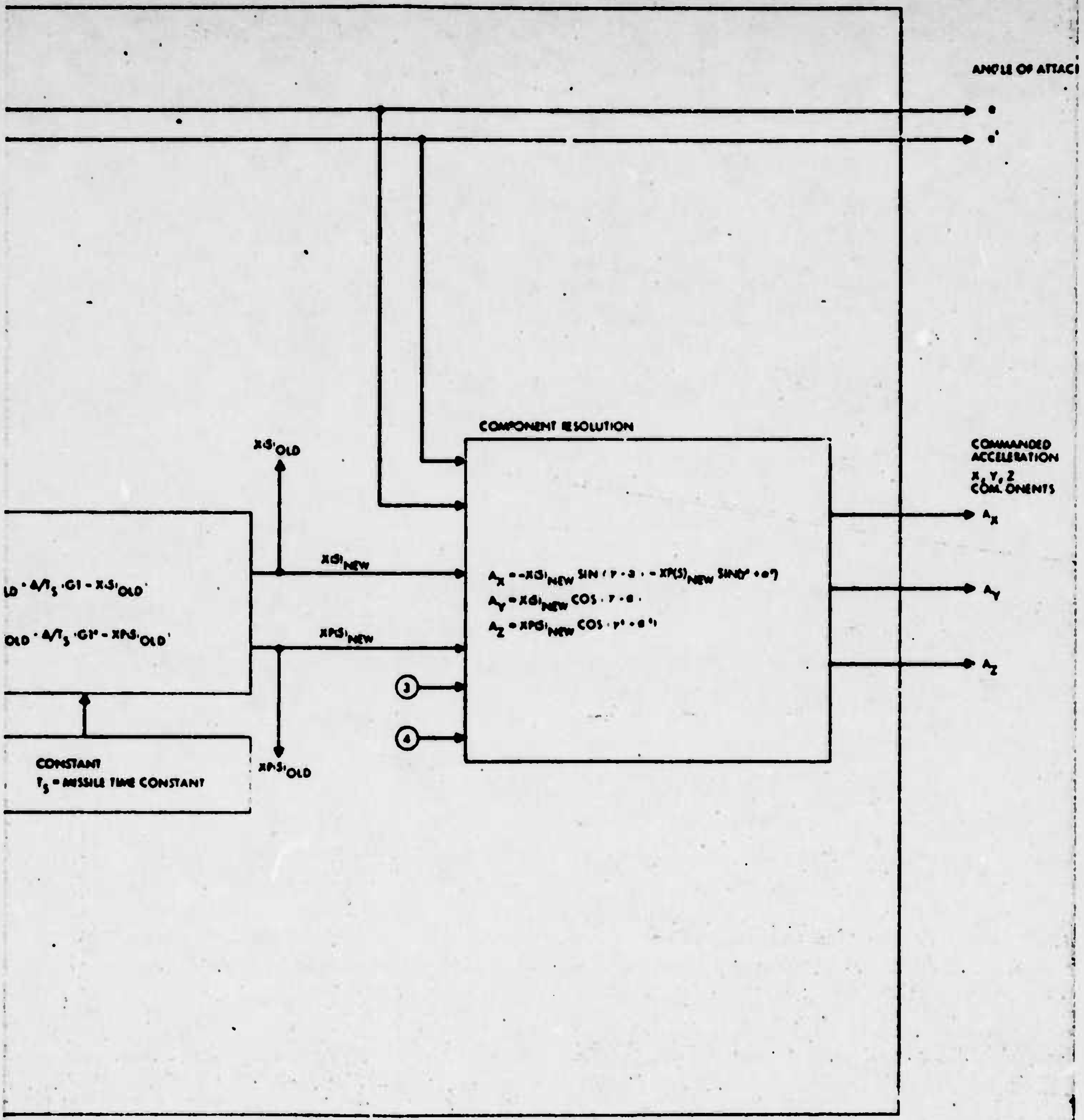

ANGLE OF ATTACK
α
α'
COMPONENT RESOLUTION
COMMANDED ACCELERATION
X, Y, Z COMPONENTS
A_X = -XS)$_{NEW}$ SIN (γ + α) - XP(S)$_{NEW}$ SIN(γ' + α')
A_Y = XS)$_{NEW}$ COS (γ + α)
A_Z = XPS)$_{NEW}$ COS (γ' + α')
A_X
A_Y
A_Z
XS'$_{OLD}$
XS)$_{NEW}$
XPS)$_{NEW}$
XPS'$_{OLD}$
LD + 4/T$_S$ (G) - XS'$_{OLD}$)
OLD + 4/T$_S$ (G)' - XPS'$_{OLD}$)
3
4
CONSTANT
T$_S$ = MISSILE TIME CONSTANT

Figure 3-6. Commanded acceleration computations

4

where,

$G1$ = commanded acceleration required (horizontal plane)

$G1'$ = commanded acceleration required (vertical plane)

$X(5)$ = actual acceleration at the control surfaces

$XP(5)$ = actual acceleration at the control surfaces (vertical)

T_s = missile time constant

The commanded force is in a direction normal to the thrust vector. It's X-, Y-, and Z-vector components are:

$$A_X = - \sin(\gamma + \alpha) * X(5)_{new} - \sin(\gamma + \alpha) \times XP(5)_{new}$$

$$A_Y = \cos(\gamma + \alpha) * X(5)_{new}$$

$$A_Z = \cos(\gamma' + \alpha') * XP(5)_{new}$$

Table 3-8 contains a listing of this subroutine.

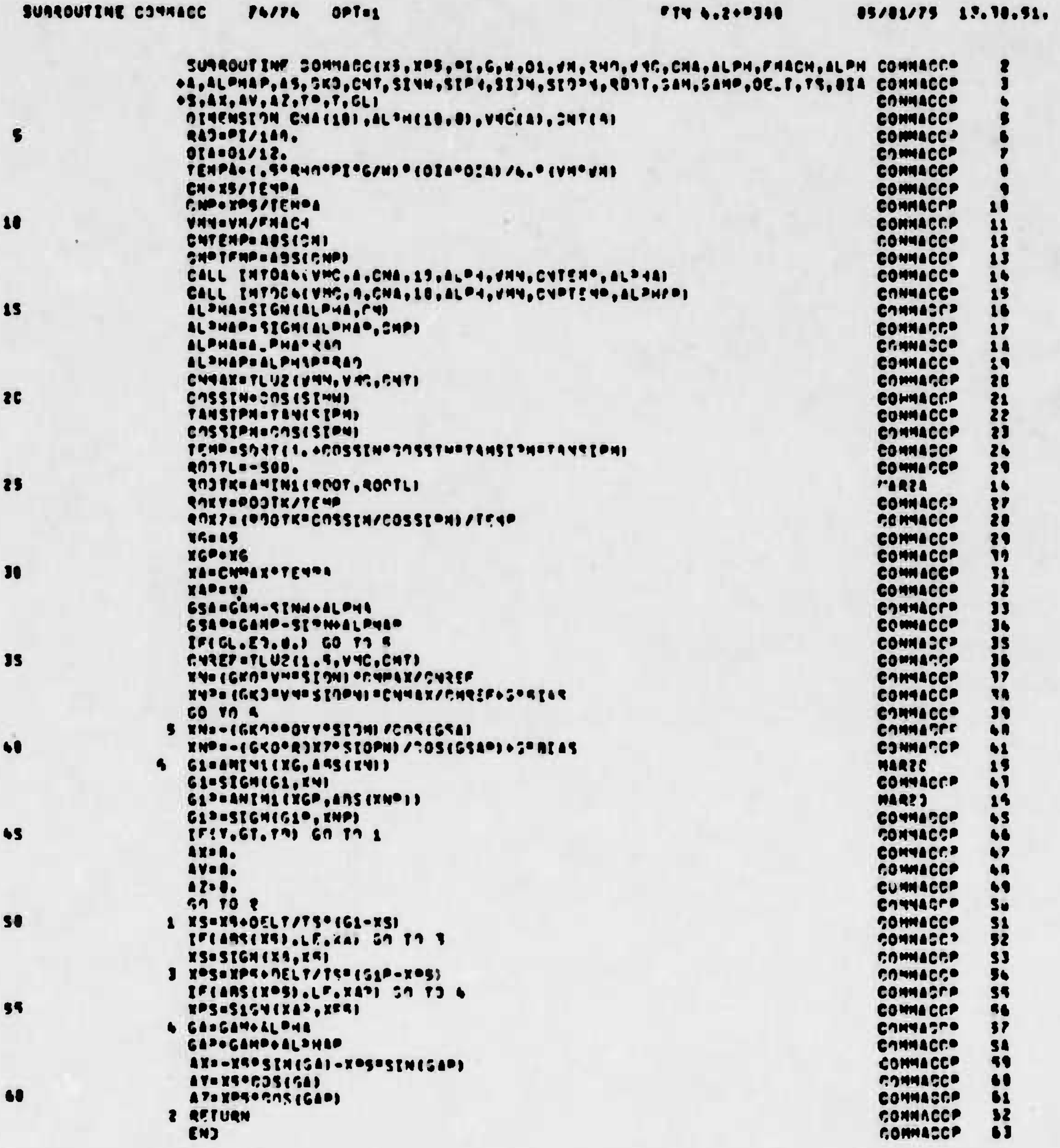
The missile angle of attack is also computed in this subroutine. One angle of attack (alpha angle) is computed for the missile in the vertical plane and one in thehorizontal plane. Curves of alpha angle as a function of Mach No. and normal force coefficient are generally available from missile specifications. This data is tabularized into a two dimensional array of alpha as a function of mach number and normal force coefficient for use in the program. The procedure for determining alpha in each plane is to compute the normal force coefficient, based on the achieved accelerations, and the mach number and then do a table lookup for alpha.

Guidance Law

In summary, the guidance law implemented in infrared missile autopilots is generally of the form

$$A_T = K_g \dot{\psi}$$

Table 3-8. Commanded acceleration subroutine



```
SUBROUTINE COMMACC    74/74    OPT=1                        FTN 4.2+P380      05/01/75  13.38.51.

                      SUBROUTINE COMMACC(XS,XPS,PI,G,W,D1,VM,RHO,VMC,CNA,ALPH,FMACH,ALPH COMMACCP    2
                     +A,ALPHAP,AS,GKO,CNT,SIMM,SIPM,SIOM,SIOPM,RDOT,GAM,GAMP,DELT,TS,BIA COMMACCP    3
                     +S,AX,AY,AZ,TP,T,GL)                                                COMMACCP    4
                      DIMENSION CNA(10),ALPH(10,8),VMC(8),CNT(8)                         COMMACCP    5
                      RAD=PI/180.                                                        COMMACCP    6
                      DIA=D1/12.                                                         COMMACCP    7
                      TEMPA=(.5*RHO*PI*G/W)*(DIA*DIA)/4.*(VM*VM)                         COMMACCP    8
                      CM=XS/TEMPA                                                        COMMACCP    9
                      CMP=XPS/TEMPA                                                      COMMACCP   10
                      VMM=VM/FMACH                                                       COMMACCP   11
                      CMTEMP=ABS(CM)                                                     COMMACCP   12
                      CMPTEMP=ABS(CMP)                                                   COMMACCP   13
                      CALL INTOA6(VMC,8,CNA,10,ALPH,VMM,CMTEMP,ALPHA)                    COMMACCP   14
                      CALL INTOA6(VMC,8,CNA,10,ALPH,VMM,CMPTEMP,ALPHAP)                  COMMACCP   15
                      ALPHA=SIGN(ALPHA,CM)                                               COMMACCP   16
                      ALPHAP=SIGN(ALPHAP,CMP)                                            COMMACCP   17
                      ALPHA=ALPHA*RAD                                                    COMMACCP   18
                      ALPHAP=ALPHAP*RAD                                                  COMMACCP   19
                      CNMAX=TLU2(VMM,VMC,CNT)                                            COMMACCP   20
                      COSSIM=COS(SIMM)                                                   COMMACCP   21
                      TANSIPM=TAN(SIPM)                                                  COMMACCP   22
                      COSSIPM=COS(SIPM)                                                  COMMACCP   23
                      TEMP=SQRT(1.+COSSIM*COSSIM*TANSIPM*TANSIPM)                        COMMACCP   24
                      RDOTL=-500.                                                        COMMACCP   25
                      RDOTK=AMIN1(RDOT,RDOTL)                                            MARZA      14
                      RDKY=RDOTK/TEMP                                                    COMMACCP   27
                      RDKZ=(RDOTK*COSSIM/COSSIPM)/TEMP                                   COMMACCP   28
                      XG=AS                                                              COMMACCP   29
                      XGP=XG                                                             COMMACCP   30
                      XA=CNMAX*TEMPA                                                     COMMACCP   31
                      XAP=XA                                                             COMMACCP   32
                      GSA=GAM-SIMM+ALPHA                                                 COMMACCP   33
                      GSAP=GAMP-SIPM+ALPHAP                                              COMMACCP   34
                      IF(GL.EQ.0.) GO TO 5                                               COMMACCP   35
                      CNREF=TLU2(1.5,VMC,CNT)                                            COMMACCP   36
                      XN=(GKO*VM*SIOM)*CNMAX/CNREF                                       COMMACCP   37
                      XNP=(GKO*VM*SIOPM)*CNMAX/CNREF+G*BIAS                              COMMACCP   38
                      GO TO 6                                                            COMMACCP   39
                    5 XN=-(GKO*RDKY*SIOM)/COS(GSA)                                       COMMACCP   40
                      XNP=-(GKO*RDKZ*SIOPM)/COS(GSAP)+G*BIAS                             COMMACCP   41
                    6 G1=AMIN1(XG,ABS(XN))                                               MARZC      15
                      G1=SIGN(G1,XN)                                                     COMMACCP   43
                      G1P=AMIN1(XGP,ABS(XNP))                                            MARZD      15
                      G1P=SIGN(G1P,XNP)                                                  COMMACCP   45
                      IF(T.GT.TP) GO TO 1                                                COMMACCP   46
                      AX=0.                                                              COMMACCP   47
                      AY=0.                                                              COMMACCP   48
                      AZ=0.                                                              COMMACCP   49
                      GO TO 2                                                            COMMACCP   50
                    1 XS=XS+DELT/TS*(G1-XS)                                              COMMACCP   51
                      IF(ABS(XS).LE.XA) GO TO 3                                          COMMACCP   52
                      XS=SIGN(XA,XS)                                                     COMMACCP   53
                    3 XPS=XPS+DELT/TS*(G1P-XPS)                                          COMMACCP   54
                      IF(ABS(XPS).LE.XAP) GO TO 4                                        COMMACCP   55
                      XPS=SIGN(XAP,XPS)                                                  COMMACCP   56
                    4 GA=GAM+ALPHA                                                       COMMACCP   57
                      GAP=GAMP+ALPHAP                                                    COMMACCP   58
                      AX=-XS*SIN(GA)-XPS*SIN(GAP)                                        COMMACCP   59
                      AY=XS*COS(GA)                                                      COMMACCP   60
                      AZ=XPS*COS(GAP)                                                    COMMACCP   61
                    2 RETURN                                                             COMMACCP   62
                      END                                                                COMMACCP   63
```

where,

A_T = commanded acceleration normal to body axis

$\dot{\psi}$ = LOS rate

K_g = navigation gain

Because the navigation gain (K_g) varies considerably with tactical conditions (altitude, launch speed, target speed, etc.) it is difficult to decide upon a fixed value for this constant when working with one missile only. When many missiles are to be evaluated, as is the case of the missile, target, and flare simulation, this guidance law becomes too difficult to implement and can lead to a large variation in missile trajectory. In order to avoid this problem, the missile, target, and flare simulation uses an ideal guidance law given by

$$A_T = \frac{\Lambda r \ddot{\psi}}{\cos(\gamma - \psi + \alpha)}$$

where these parameters are defined in Table 1. It should be pointed out that this law is impossible to impiement in IR missile hardware due to the fact that missile and target range rate information is required. However, it does enable the simulation to remain generic and to evaluate missile performance under ideal conditions.

The guidance law of the form $K_g\dot{\psi}$ can also be implemented in the simulation, particularly when statistical variations in missile trajectory are desired. This can be accomplished easily by varying the navigation gain over its range of values.

The commanded missile acceleration normal to the line-of-sight (LOS) for ideal proportional navigation is given by

$$A_N = \Lambda V_C \dot{\psi}$$

Figure 3-7 shows the reference geometry and Table 3-9 defines the glossary of terms.

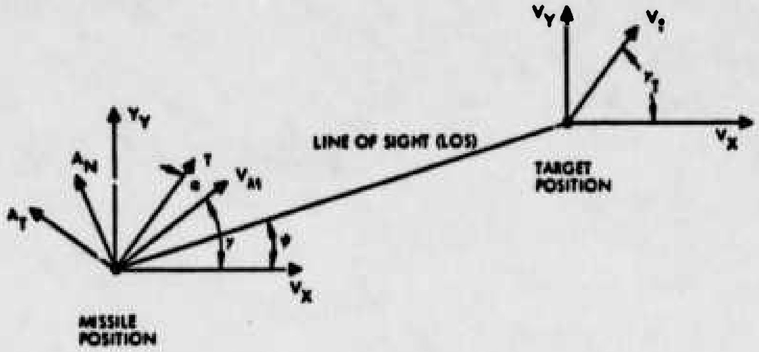


Figure 3-7. Missile and target reference geometry

In actual practice, the commanded acceleration is directed normally to the body axis and given by

$$A_T = \frac{\Lambda \dot{r} \dot{\psi}}{\cos \alpha \cos (\alpha - \psi)}$$

This relationship is the equation for implementing the proportional navigation law in the ideal case, and is presently the equation used in the missile, target, and flare simulation.

From the infrared missile hardware point of view, this equation is impossible to implement because range rate information is not available to the missile. The equation generally implemented in the autopilot of infrared missiles is

$$A_T = K_g \dot{\psi} \qquad (3\text{-}8)$$

where

$$K_g = \frac{\Lambda V_c}{\cos (\gamma - \psi + \alpha)} \qquad (3\text{-}9)$$

Table 3-9. Glossary of terms

V_x, V_y	=	inertial reference axes
V_T	=	target velocity
γ_T	=	angle between target velocity and inertial axis
V_m	=	missile velocity
γ	=	angle between missile velocity and inertial axis
ψ	=	angle between LOS and inertial axis
$\dot{\psi}$	=	LOS rate
α	=	angle of attack
T	=	missile body axis direction
$\dot{r}$	=	range rate along LOS
V_c	=	missile/target closing velocity
A_N	=	missile acceleration normal to LOS
A_T	=	missile acceleration normal to body axis
Λ	=	navigation parameter
K_g	=	navigation gain

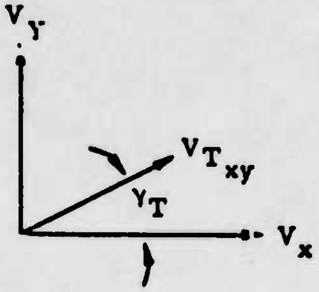
The parameter K_g is set before launch and is a function of altitude, target speed, and launch speed. This constant is normally chosen to be three times the maximum closing velocity achieved by the missile during flight. This ensures that the minimum value of the navigation parameter will be 3. The values during flight will be higher, ranging up to 5 or more at the end of flight. The constant value of 4 used in the simulation is an approximation of the average value during an actual flight. This is somewhat optimistic from the missile point of view.

3.2 TARGET EQUATIONS

The program allows for four different types of flight paths to be flown by the target aircraft. These include: straight and level, circular turn, straight acceleration, and turn and tangential acceleration.

All target motion is considered to take place only in the horizontal X-Y plane, and the equations governing each flight path are given in Tables 3-10 through 3-13.

Table 3-10. Straight and level flight



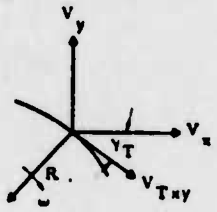
Equations

$$V_{Tx} = V_T \cos \gamma_T$$

$$V_{Ty} = V_T \sin \gamma_T$$

$$V_{Tz} = 0$$

Table 3-11. Circular turn



V_x, V_y, V_z = reference axes (V_z not shown)

R = turn radius

V_{Txy} = total velocity of aircraft in xy plane

γ_T = angle between aircraft velocity vector (xy plane only) and V_x reference axis

ω = rate of angular rotation of aircraft in the turn

V_{Tx}, V_{Ty}, V_{Tz} = components of aircraft velocity along reference axes

M_g = Integral number of g's that aircraft pulls in the turn

$M_g > 0$ for left turn

$M_g < 0$ for right turn

T_M = time maneuver begins

g = gravitational constant

T = time

Equations

$$M_g g = \frac{V_{T_{xy}}^2}{R}$$

$$R = \frac{V_{T_{xy}}^2}{M_g g}$$

$$\omega = \frac{V_{Txy}}{R} = \frac{M_g g}{V_{Txy}}$$

If $T < T_M$, then

$$\gamma_T = \gamma_T$$

Otherwise,

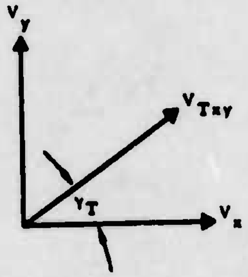
$$\gamma_T = \gamma_T(T_M) + \omega(T - T_M)$$

$$V_{Tx} = V_{Txy} \cos \gamma_T$$

$$V_{Ty} = V_{Txy} \sin \gamma_T$$

$$V_{Tz} = 0$$

Table 3-12. Straight acceleration



A_m = maximum furward acceleration of aircraft in g's

$V_m(h)$ = maximum aircraft speed at altitude (h)

V_T = total velocity of aircraft

Δ_T = size of integration step

Note. All previous definitions are applicable.

<u>Equations</u>

$$V_{Tx}\,(\text{new}) = V_{Tx}\,(\text{old}) + \dot{V}_x \Delta t$$

$$V_{Ty}\,(\text{new}) = V_{Ty}\,(\text{old}) + \dot{V}_y \Delta t$$

$$V_{Tz} = 0$$

If $T < T_M$ or $V_T \geq V_M(h)$, then

$$\dot{V}_x = \dot{V}_y = 0$$

Otherwise,

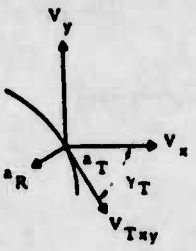
(Note: The target mode of operation is changed from military power to afterburner at $t = T_M$)

$$\dot{V}_x = A_m g \cos \gamma_T$$

$$\dot{V}_y = A_m g \sin \gamma_T$$

$$\dot{V}_z = 0$$

Table 3-13. Turn and acceleration



a_R = radial component of aircraft acceleration

a_T = tangential component of aircraft acceleration

Equations

$$V_{Txy}(\text{new}) = V_{Txy}(\text{old}) + \dot{V}_{Txy} g\Delta t$$

$$\gamma_T(\text{new}) = \gamma_T(\text{old}) + \dot{\gamma}_T \Delta t$$

$$V_{Tx} = V_{Txy} \cos \gamma_T$$

$$V_{Ty} = V_{Txy} \sin \gamma_T$$

$$V_{Tz} = 0$$

when

$$T < T_M$$

$$\dot{\gamma}_T = 0$$

$$V_{Txy} = 0$$

$$T > T_M$$

(Note: The target mode of operation is changed from military power to afterburner at $t = T_M$.)

If

$$V_T \leq V_M(h)$$

then

$$\dot{V}_{Txy} = a_T = A_M g$$

$$\dot{\gamma}_T = \frac{a_R}{V_{Txy}} = \frac{M_g g}{V_{Txy}}$$

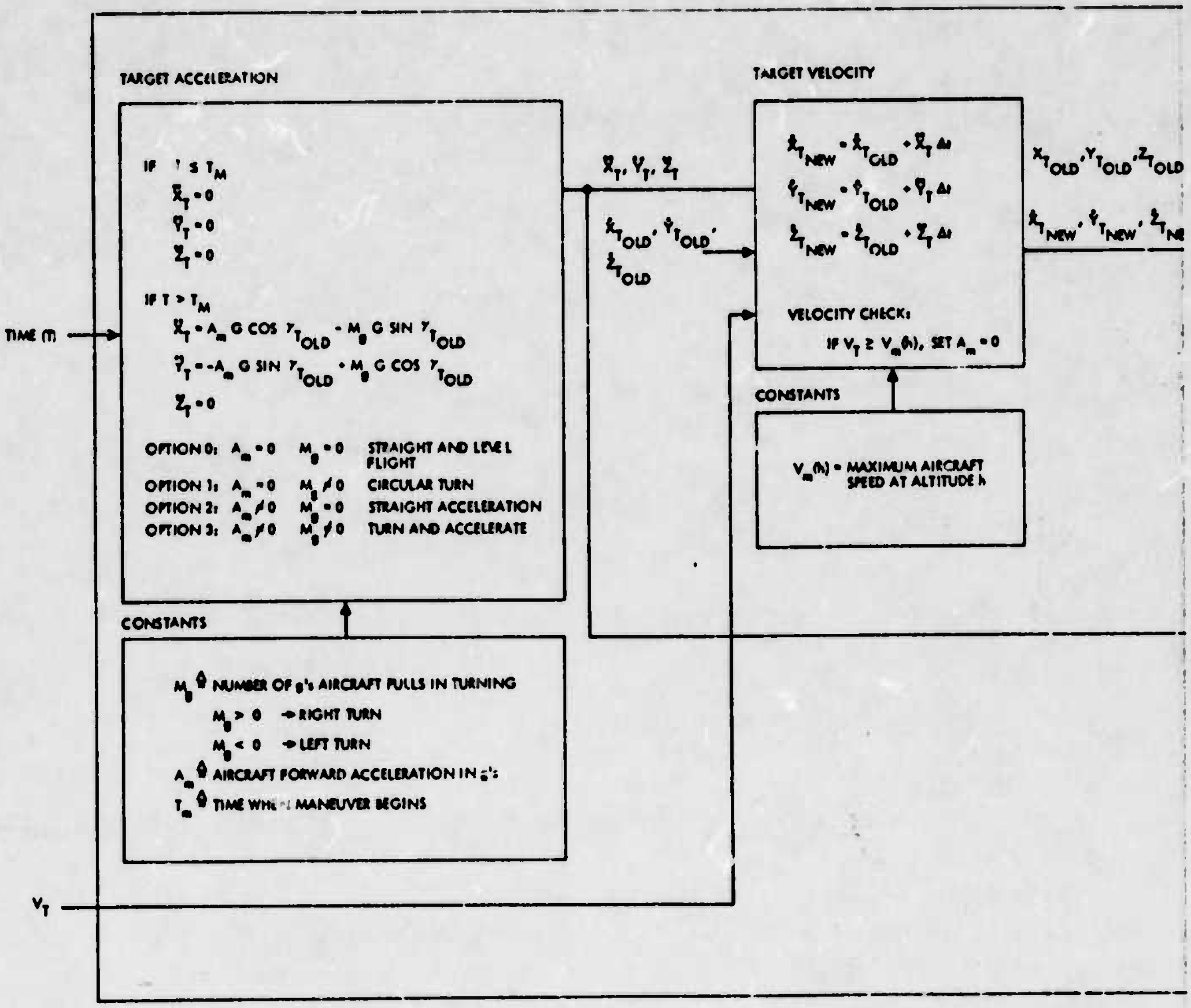
If not,

$$\dot{V}_{Txy} = 0$$

$$\dot{\gamma}_T = \frac{M_g g}{V_{Txy}}$$

The target altitude and velocity is an initial input into the program. The target heading relative to the inertial axes is determined in the program by missile aspect angle at launch. The additional aircraft data required to effect the maneuvers includes the maximum number of g's the aircraft can pull in a turn, the maximum aircraft acceleration forward, and the maximum speed it can obtain.

Figure 3-8 shows the basic equations used in the program to simulate target motion. Target maneuvers are controlled through NAMELIST input variables TM, AM, FMG. The time of initiation of maneuver is set by TM. Linear acceleration AM, and target turns FMG, are input as the magnitude of the acceleration(s) in terms of the number of g's. A positive sign for FMG will generate a right turn and a negative sign a left turn. Table 3-14 contains a listing of this subroutine.


TARGET ACCELERATION
IF T ≤ T_M
$\ddot{X}_T = 0$
$\ddot{Y}_T = 0$
$\ddot{Z}_T = 0$
IF T > T_M
$\ddot{X}_T = A_m G \cos \gamma_{T_{OLD}} - M_g G \sin \gamma_{T_{OLD}}$
$\ddot{Y}_T = -A_m G \sin \gamma_{T_{OLD}} + M_g G \cos \gamma_{T_{OLD}}$
$\ddot{Z}_T = 0$
OPTION 0: $A_m = 0$ $M_g = 0$ STRAIGHT AND LEVEL FLIGHT
OPTION 1: $A_m = 0$ $M_g \neq 0$ CIRCULAR TURN
OPTION 2: $A_m \neq 0$ $M_g = 0$ STRAIGHT ACCELERATION
OPTION 3: $A_m \neq 0$ $M_g \neq 0$ TURN AND ACCELERATE
TIME (T)
CONSTANTS
$M_g \triangleq$ NUMBER OF g's AIRCRAFT PULLS IN TURNING
$M_g > 0$ → RIGHT TURN
$M_g < 0$ → LEFT TURN
$A_m \triangleq$ AIRCRAFT FORWARD ACCELERATION IN g's
$T_m \triangleq$ TIME WHEN MANEUVER BEGINS
V_T
$\ddot{X}_T, \ddot{Y}_T, \ddot{Z}_T$
$\dot{X}_{T_{OLD}}, \dot{Y}_{T_{OLD}}, \dot{Z}_{T_{OLD}}$
TARGET VELOCITY
$\dot{X}_{T_{NEW}} = \dot{X}_{T_{OLD}} + \ddot{X}_T \Delta t$
$\dot{Y}_{T_{NEW}} = \dot{Y}_{T_{OLD}} + \ddot{Y}_T \Delta t$
$\dot{Z}_{T_{NEW}} = \dot{Z}_{T_{OLD}} + \ddot{Z}_T \Delta t$
VELOCITY CHECK:
IF $V_T \geq V_m(h)$, SET $A_m = 0$
CONSTANTS
$V_m(h)$ = MAXIMUM AIRCRAFT SPEED AT ALTITUDE h
$X_{T_{OLD}}, Y_{T_{OLD}}, Z_{T_{OLD}}$
$\dot{X}_{T_{NEW}}, \dot{Y}_{T_{NEW}}, \dot{Z}_{T_{NE}}$

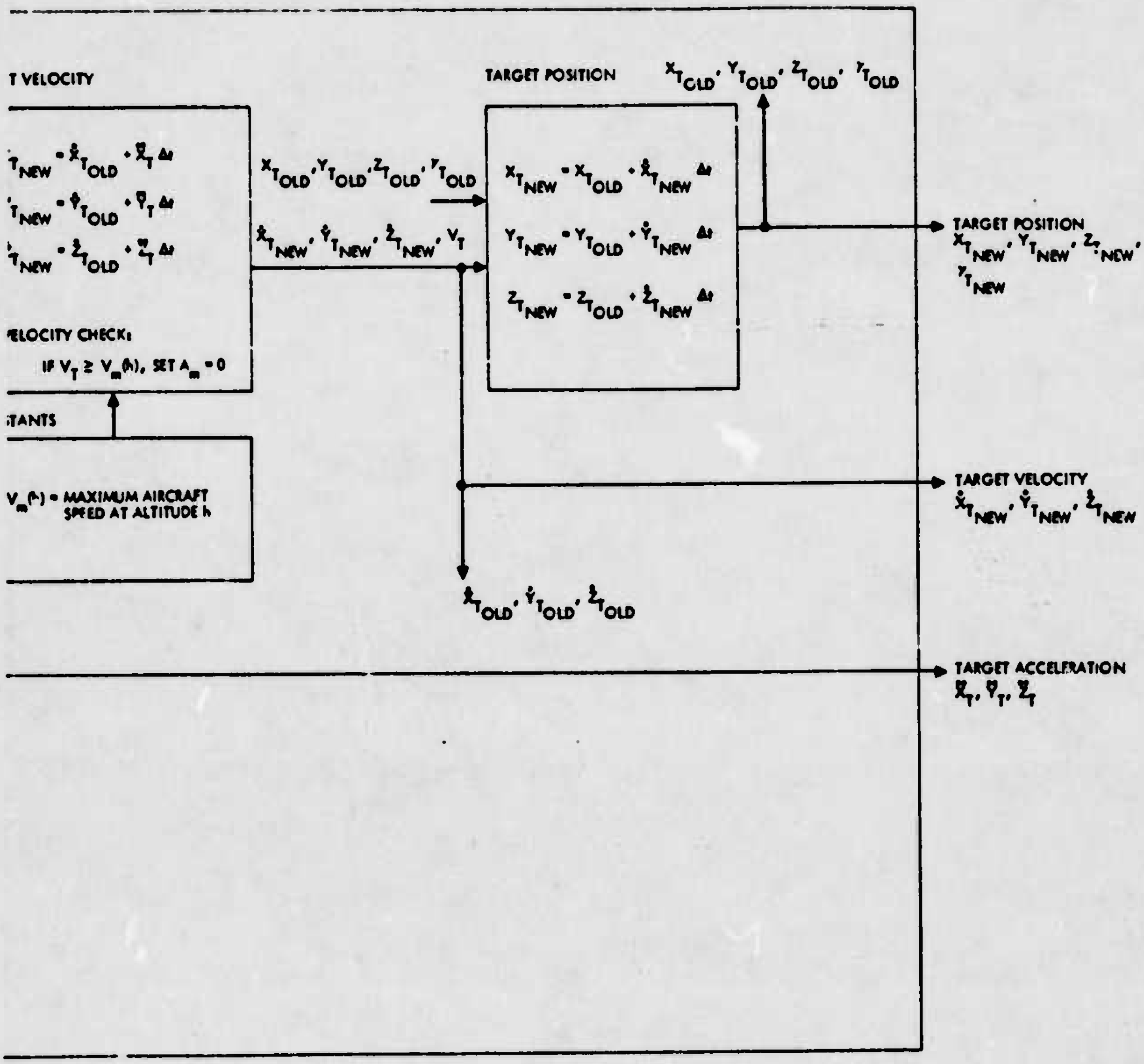

T VELOCITY
$\dot{X}_{T_{NEW}} = \dot{X}_{T_{OLD}} + \ddot{X}_T \Delta t$
$\dot{Y}_{T_{NEW}} = \dot{Y}_{T_{OLD}} + \ddot{Y}_T \Delta t$
$\dot{Z}_{T_{NEW}} = \dot{Z}_{T_{OLD}} + \ddot{Z}_T \Delta t$
VELOCITY CHECK:
IF $V_T \geq V_m(h)$, SET $A_m = 0$
TANTS
$V_m(h)$ = MAXIMUM AIRCRAFT SPEED AT ALTITUDE h
$X_{T_{OLD}}, Y_{T_{OLD}}, Z_{T_{OLD}}, \gamma_{T_{OLD}}$
$\dot{X}_{T_{NEW}}, \dot{Y}_{T_{NEW}}, \dot{Z}_{T_{NEW}}, V_T$
TARGET POSITION
$X_{T_{NEW}} = X_{T_{OLD}} + \dot{X}_{T_{NEW}} \Delta t$
$Y_{T_{NEW}} = Y_{T_{OLD}} + \dot{Y}_{T_{NEW}} \Delta t$
$Z_{T_{NEW}} = Z_{T_{OLD}} + \dot{Z}_{T_{NEW}} \Delta t$
$X_{T_{OLD}}, Y_{T_{OLD}}, Z_{T_{OLD}}, \gamma_{T_{OLD}}$
TARGET POSITION
$X_{T_{NEW}}, Y_{T_{NEW}}, Z_{T_{NEW}}, \gamma_{T_{NEW}}$
TARGET VELOCITY
$\dot{X}_{T_{NEW}}, \dot{Y}_{T_{NEW}}, \dot{Z}_{T_{NEW}}$
$\dot{X}_{T_{OLD}}, \dot{Y}_{T_{OLD}}, \dot{Z}_{T_{OLD}}$
TARGET ACCELERATION
$\ddot{X}_T, \ddot{Y}_T, \ddot{Z}_T$

Figure 3-8. Target dynamics

2

Table 3-14. Target motion subroutine

```
SUBROUTINE TGDYN      74/74    OPT=1                        FTN 4.2+P380       09/01/75  13.31.09.

                SUBROUTINE TGDYN(T,TM,DELT,AM,G,FMG,VM,VT,X6,X8,XP8,X7,X9,XP9,X   MAR19     69
               +7D,X9D,XP9D,GAMT)                                                 TGTDYNAM   3
                IF(T.GT.TM) GO TO 1                                               TGTDYNAM   4
                X7D=0.                                                            TGTDYNAM   5
                X9D=0.                                                            TGTDYNAM   6
                XP9D=0.                                                           TGTDYNAM   7
                GO TO 2                                                           TGTDYNAM   8
              1 X7D=AM*G*COS(GAMT)-FMG*G*SIN(GAMT)                                TGTDYNAM   9
                X9D=-AM*G*SIN(GAMT)+FMG*G*COS(GAMT)                               TGTDYNAM  10
                XP9D=0.                                                           TGTDYNAM  11
              2 X7=X7+X7D*DELT                                                    TGTDYNAM  12
                X9=X9+X9D*DELT                                                    TGTDYNAM  13
                XP9=XP9+XP9D*DELT                                                 TGTDYNAM  14
                IF(VT.GE.VM) AM=0.                                                TGTDYNAM  15
                X6=X6+X7*DELT                                                     TGTDYNAM  16
                X8=X8+X9*DELT                                                     TGTDYNAM  17
                XP8=XP8+XP9*DELT                                                  TGTDYNAM  18
                RETURN                                                            TGTDYNAM  19
                END                                                               TGTDYNAM  20
```

3.3 FLARE CONTROL AND DYNAMICS

Figure 3-9 shows a block diagram of the major computations performed in this section. Basically, the flare control portion of this problem is responsible for determining the flare status (not dispensed, burning, or extinguished), the times at which flares are ejected, and the initial velocity and position of the flares at ejection. The flare dynamics updates the flare trajectory for those flares which have been dispensed and are still burning.

Flare Control

The flare status as indicated in Figure 3-10 is controlled by the variable NM(k), with NM(k) = 1 indicating that the flare has not yet been dispensed, NM(k) = 2 indicating that the flare has been dispensed and is still burning, and NM(k) = 3 indicating that the flare has been extinguished. The flare initial deployment strategy is also under the control of this portion of the program. Figure 3-10 shows that flares can be dispensed as a function of (1) time after missile launch, (2) missile and target range, (3) time to go, and (4) missile and target range rate.

Once a flare has been deployed, the flare's initial velocity is computed based on the target velocity plus the dispenser ejection velocity. This includes the ejection direction. The flare's position is computed based on target position plus dispenser location relative to engine(s) position. A listing of this subroutine is contained in Table 3-15.

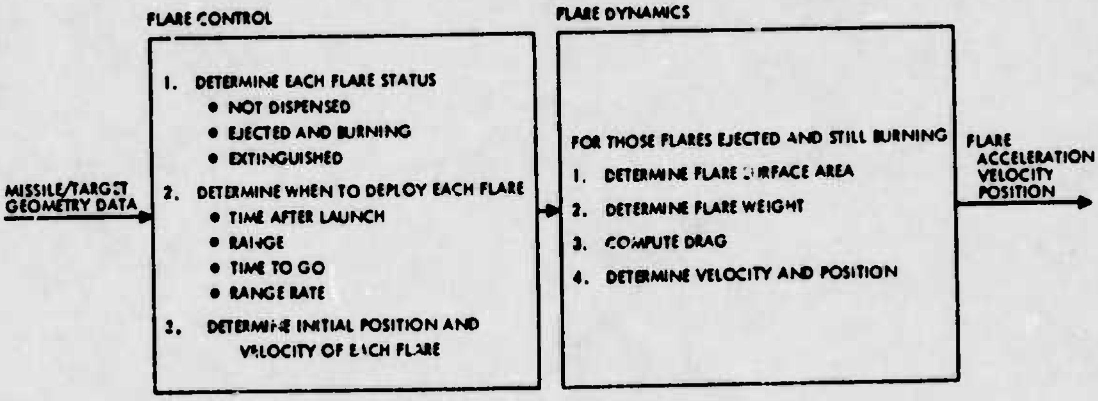
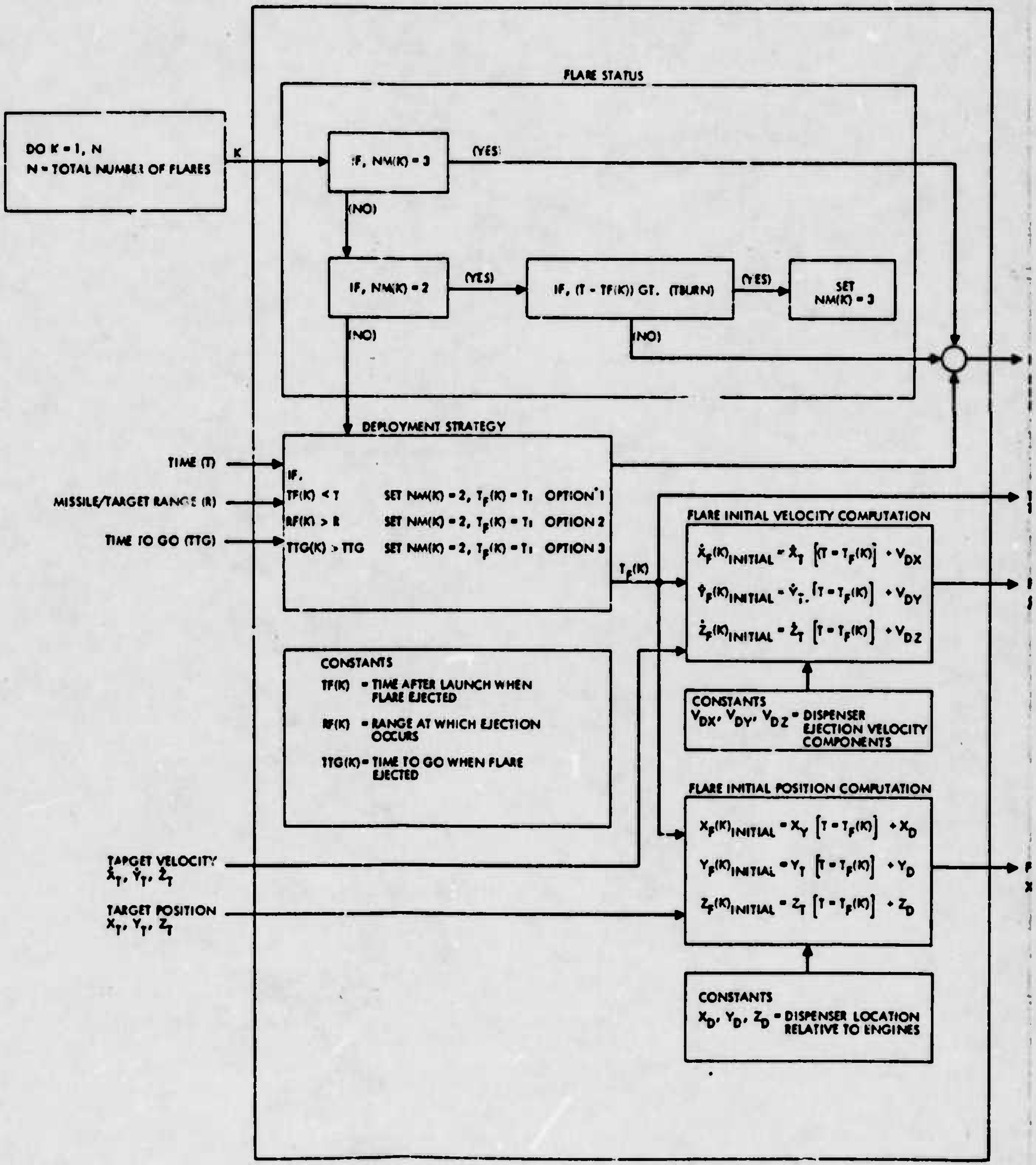

FLARE CONTROL
1. DETERMINE EACH FLARE STATUS
• NOT DISPENSED
• EJECTED AND BURNING
• EXTINGUISHED
2. DETERMINE WHEN TO DEPLOY EACH FLARE
• TIME AFTER LAUNCH
• RANGE
• TIME TO GO
• RANGE RATE
3. DETERMINE INITIAL POSITION AND VELOCITY OF EACH FLARE
FLARE DYNAMICS
FOR THOSE FLARES EJECTED AND STILL BURNING
1. DETERMINE FLARE SURFACE AREA
2. DETERMINE FLARE WEIGHT
3. COMPUTE DRAG
4. DETERMINE VELOCITY AND POSITION
MISSILE/TARGET GEOMETRY DATA
FLARE ACCELERATION VELOCITY POSITION

Figure 3-9. Flare control and dynamics overview


DO K = 1, N
N = TOTAL NUMBER OF FLARES
K
FLARE STATUS
IF, NM(K) = 3
(YES)
(NO)
IF, NM(K) = 2
(YES)
IF, (T - TF(K)) GT. (TBURN)
(YES)
SET NM(K) = 3
(NO)
(NO)
DEPLOYMENT STRATEGY
TIME (T)
MISSILE/TARGET RANGE (R)
TIME TO GO (TTG)
IF,
TF(K) < T   SET NM(K) = 2, $T_F(K) = T$ OPTION 1
RF(K) > R   SET NM(K) = 2, $T_F(K) = T$ OPTION 2
TTG(K) > TTG   SET NM(K) = 2, $T_F(K) = T$ OPTION 3
$T_F(K)$
CONSTANTS
TF(K) = TIME AFTER LAUNCH WHEN FLARE EJECTED
RF(K) = RANGE AT WHICH EJECTION OCCURS
TTG(K) = TIME TO GO WHEN FLARE EJECTED
FLARE INITIAL VELOCITY COMPUTATION
$\dot{X}_F(K)_{INITIAL} = \dot{X}_T \left[T = T_F(K)\right] + V_{DX}$
$\dot{Y}_F(K)_{INITIAL} = \dot{Y}_T \left[T = T_F(K)\right] + V_{DY}$
$\dot{Z}_F(K)_{INITIAL} = \dot{Z}_T \left[T = T_F(K)\right] + V_{DZ}$
CONSTANTS
V_{DX}, V_{DY}, V_{DZ} = DISPENSER EJECTION VELOCITY COMPONENTS
FLARE INITIAL POSITION COMPUTATION
$X_F(K)_{INITIAL} = X_Y \left[T = T_F(K)\right] + X_D$
$Y_F(K)_{INITIAL} = Y_T \left[T = T_F(K)\right] + Y_D$
$Z_F(K)_{INITIAL} = Z_T \left[T = T_F(K)\right] + Z_D$
CONSTANTS
X_D, Y_D, Z_D = DISPENSER LOCATION RELATIVE TO ENGINES
TARGET VELOCITY
$\dot{X}_T, \dot{Y}_T, \dot{Z}_T$
TARGET POSITION
X_T, Y_T, Z_T

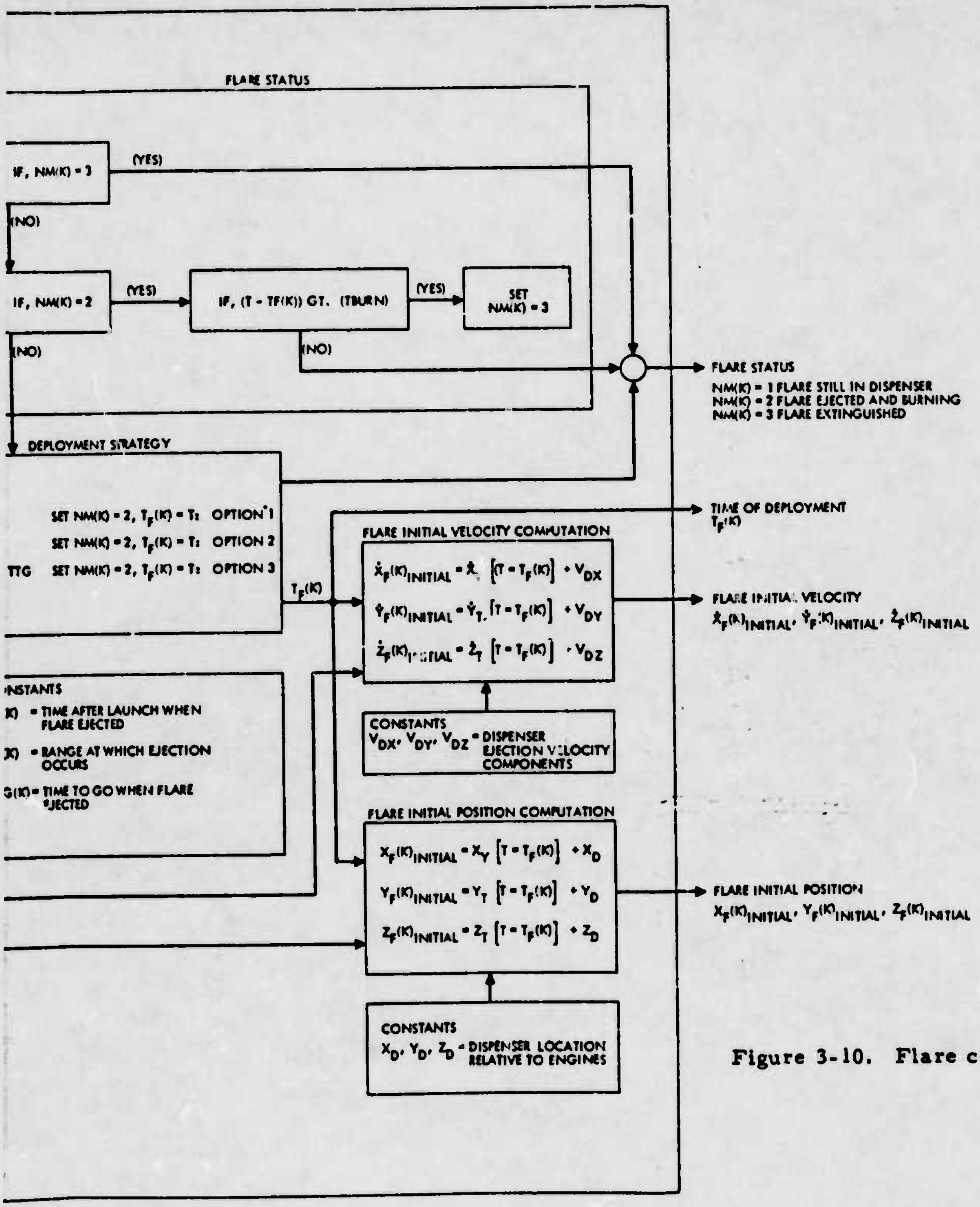

FLARE STATUS
IF, NM(K) = 3
(YES)
(NO)
IF, NM(K) = 2
(YES)
IF, (T - TF(K)) GT. (TBURN)
(YES)
SET NM(K) = 3
(NO)
(NO)
FLARE STATUS
NM(K) = 1 FLARE STILL IN DISPENSER
NM(K) = 2 FLARE EJECTED AND BURNING
NM(K) = 3 FLARE EXTINGUISHED
DEPLOYMENT STRATEGY
SET NM(K) = 2, $T_F(K)$ = T: OPTION*1
SET NM(K) = 2, $T_F(K)$ = T: OPTION 2
TTG SET NM(K) = 2, $T_F(K)$ = T: OPTION 3
$T_F(K)$
TIME OF DEPLOYMENT $T_F(K)$
FLARE INITIAL VELOCITY COMPUTATION
$\dot{X}_F(K)_{INITIAL} = \dot{X}_T\ [T - T_F(K)] + V_{DX}$
$\dot{Y}_F(K)_{INITIAL} = \dot{Y}_T\ [T - T_F(K)] + V_{DY}$
$\dot{Z}_F(K)_{INITIAL} = \dot{Z}_T\ [T - T_F(K)] + V_{DZ}$
FLARE INITIAL VELOCITY
$\dot{X}_F(K)_{INITIAL}, \dot{Y}_F(K)_{INITIAL}, \dot{Z}_F(K)_{INITIAL}$
CONSTANTS
V_{DX}, V_{DY}, V_{DZ} = DISPENSER EJECTION VELOCITY COMPONENTS
NSTANTS
K) = TIME AFTER LAUNCH WHEN FLARE EJECTED
K) = RANGE AT WHICH EJECTION OCCURS
G(K) = TIME TO GO WHEN FLARE EJECTED
FLARE INITIAL POSITION COMPUTATION
$X_F(K)_{INITIAL} = X_Y\ [T - T_F(K)] + X_D$
$Y_F(K)_{INITIAL} = Y_T\ [T - T_F(K)] + Y_D$
$Z_F(K)_{INITIAL} = Z_T\ [T - T_F(K)] + Z_D$
FLARE INITIAL POSITION
$X_F(K)_{INITIAL}, Y_F(K)_{INITIAL}, Z_F(K)_{INITIAL}$
CONSTANTS
X_D, Y_D, Z_D = DISPENSER LOCATION RELATIVE TO ENGINES

Figure 3-10. Flare control

2

Table 3-15. Flare control subroutine

```
SUBROUTINE FLRCTRL     74/74    OPT=1                               FTN 4.2+P383        05/31/75  17.30.56.

          SUBROUTINE FLRCTRL(NN,N,IGT,T,TF,TTG,TTGF,SSW2,XF,XFP,X,XP,TBURN     MAR19      48
         *,VXF,VYF,VZF,XO,YO,ZO,REL,RF,ROF,IOPLOY,M,PI,Z)                      FLRCONTR    3
          DIMENSION NN(20),IGT(20,2),TF(20),SF(20),HF(20),XF(10,20)            FLRCONTR    4
          DIMENSION XFP(10,20),X(10),XP(10),VXF(20),VYF(20),VZF(20),REL(12)    FLRCONTR    5
          DIMENSION RF(20),ROF(20),TTGF(20),Z(14)                              FLRCONTR    6
          IF(N.EQ.21) GO TO 9                                                  FLRCONTR    7
          GO TO (2,3,4), IOPLOY                                                FLRCONTR    8
        2 IF(TF(N).GT.T) GO TO 13                                              FLRCONTR    9
          GO TO 9                                                              FLRCONTR   10
        3 IF(RF(N).LE.REL(10)) GO TO 10                                        FLRCONTR   11
          GO TO 12                                                             FLRCONTR   12
        4 IF(N.GT.1) GO TO 22                                                  FLRCONTR   13
          IF(TTG) 10,10,22                                                     FLRCONTR   14
       22 IF(TTGF(N).LE.TTG) GO TO 13                                          FLRCONTR   15
       12 TF(N)=T                                                              FLRCONTR   16
        9 N=N+1                                                                FLRCONTR   17
          M=N-1                                                                FLRCONTR   18
          GT=Z(7)+SIGN(PI/2.,VYF(M))                                           FLRCONTR   19
          VXF(M)=ABS(VYF(M))*COS(GT)                                           FLRCONTR   20
          VYF(M)=ABS(VYF(M))*SIN(GT)                                           FLRCONTR   21
          GO TO 20                                                             FLRCONTR   22
       10 IF(N.EQ.1) GO TO 21                                                  FLRCONTR   23
       20 DO 1 K=1,M                                                           FLRCONTR   24
          GO TO (7,6,1), NN(K)                                                 FLRCONTR   25
        6 IF((T-TF(K)).LT.(TBURN-.1)) GO TO 1                                  FLRCONTR   26
          NN(K)=3                                                              FLRCONTR   27
          IGT(K,2)=1                                                           FLRCONTR   28
          IF(SSW2.EQ.0.) GO TO 1                                               FLRCONTR   29
          IF(XFP(8,K).LE.0.) GO TO 1                                           FLRCONTR   30
          WRITE(6,14) K,T                                                      FLRCONTR   31
       14 FORMAT(/,6X,14HFLARE NUMBER  ,I4,2X,22HEXTINGUISHED AT TIME  ,F6.3 FLRCONTR   32
         *)                                                                    FLRCONTR   33
          GO TO 1                                                              FLRCONTR   34
        7 NN(K)=2                                                              FLRCONTR   35
          IGT(K,1)=1                                                           FLRCONTR   36
          IGT(K,2)=0                                                           FLRCONTR   37
          XF(7,K)=X(7)+VXF(K)                                                  FLRCONTR   38
          XF(9,K)=X(9)+VYF(K)                                                  FLRCONTR   39
          XFP(9,K)=XP(9)+VZF(K)                                                FLRCONTR   40
          XFP(6,K)=X(5)                                                        FLRCONTR   41
          XFP(7,K)=X(7)+VXF(K)                                                 FLRCONTR   42
          XF(6,K)=X(6)+XO                                                      FLRCONTR   43
          XF(8,K)=X(8)+YO                                                      FLRCONTR   44
          XFP(6,K)=XP(8)+ZO                                                    FLRCONTR   45
          IF(SSW2.EQ.0.) GO TO 1                                               FLRCONTR   46
          WRITE(6,670) K,T                                                     FLRCONTR   47
      670 FORMAT(/,6X,14HFLARE NUMBER  ,I4,2X,17HEJECTED AT TIME  ,F6.3)       FLRCONTR   48
          WRITE(6,677) K                                                       FLRCONTR   49
      677 FORMAT(6X,7HNUMBER ,I4,1X,14HFLARE POSITION)                         FLRCONTR   50
          WRITE(6,676) XF(6,K),XF(8,K),XFP(8,K)                                FLRCONTR   51
          WRITE(6,672) K                                                       FLRCONTR   52
      672 FORMAT(6X,7HNUMBER ,I4,1X,22HFLARE INITIAL VELOCITY)                 FLRCONTR   53
          WRITE(6,675) XF(7,K),XF(9,K),XFP(9,K)                                FLRCONTR   54
      676 FORMAT(2X,3HXF=,F10.2,2X,3HYF=,F10.4,2X,3HZF=,F10.4)                 FLRCONTR   55
      675 FORMAT(2X,4HVXF=,F9.4,2X,4HVYF=,F9.4,2X,4HVZF=,F9.4)                 FLRCONTR   56
          WRITE(6,13) K,T                                                      FLRCONTR   57
       13 FORMAT(/,6X,14HFLARE NUMBER  ,I4,2X,17HIGNITED AT TIME  ,F6.3)       FLRCONTR   58
        1 CONTINUE                                                             FLRCONTR   59
       21 RETURN                                                               FLRCONTR   60
          END                                                                  FLRCONTR   61
```

Flare Dynamics

In any missile, target, and flare simulation, it is vital that the trajectory time histories of the flares under consideration be known. Table 3-16 shows the two forces acting on the flare, drag and gravity, as well as the magnitude of each. The following equation governing the trajectory time history can then be written:

$$\dot{\vec{V}}_F = -\left(\frac{1}{2}\ pA_sC_D(G/W_F)V_F\vec{V}_F + G\right)$$

where

p = atmospheric density

C_D = drag coefficient

A_s = cross-sectional area

W_F = weight of flare

V_F = velocity of flare

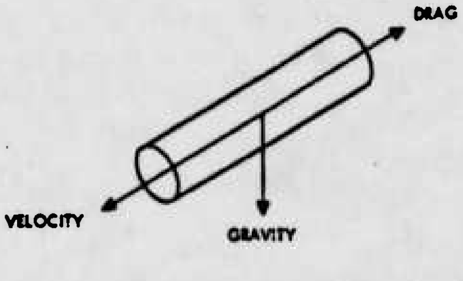
G = gravitational constant

The major difficulties in solving this equation are that both the cross-sectional area and the weight are time dependent functions, while the cross-sectional area is spatially dependent if the flare is tumbling (as it normally does).

To deal with the spatial orientation problem, it is assumed that a cross-sectional area averaged over all surfaces will account for this orientation of the flare as it tumbles. Then, the cross-sectional area (SFB) presented to the wind stream will be the average of longitudinal (A2) and axial cross sectional area or

$$SFB = \frac{A1 + A2}{2}$$

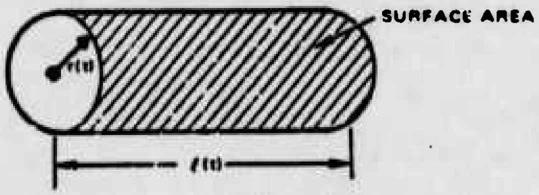
Table 3-16. Forces acting on the Kth flare



FORCE	MAGNITUDE	
	HORIZONTAL PLANE	VERTICAL PLANE
GRAVITY	0	$W_F(K)$
DRAG	$1/2 \cdot \rho \cdot C_D \cdot S_F(K) \cdot V_F^2(K)$	

$W_F(K)$ = WEIGHT OF Kth FLARE
$V_F(K)$ = VELOCITY OF Kth FLARE
$S_F(K)$ = SURFACE AREA OF Kth FLARE NORMAL TO VELOCITY VECTOR
C_D = DRAG COEFFICIENT

Now consider cylindrical flares such as the MK-46, MK-49, and ALA-17. Assume that the linear burn rate is constant, and that the area of the cylinder walls is much greater than that of the ends of the cylinder. This is a good assumption in view of the shapes of the flares being investigated. However, if the area of the ends of the cylinders are neglected and the definitions in the sketch below are used, the perimeter surface area can be expressed as



$A(t) = 2\pi r(t)\, l(t)$

On the assumption that the linear burn rate is constant and that the radius of the cylinder is much shorter than the length of the cylinder, it follows that dr/dt = constant. The solution to this equation is

$$r(t) = r_o(1 - t/t_B)$$

where

r_o = initial radius of flare

t_B = burn time

If a similar expression for $\ell(t)$ is assumed, which is not necessarily the exact solution for this term but one that should result in an adequate approximation, the expression for the $\ell(t)$ becomes

$$\ell(t) = \ell_o (1 - t/t_B)$$

For cylindrical type flares,

$$A1(t) = \pi r^2(t)$$

and

$$A2(t) = 2r(t)\ell(t) \pi$$

The average cross-sectional area is

$$SFB(t) = \frac{A1(t) + A2(t)}{2} = \frac{\pi r^2(t)}{2} + \frac{2r(t) \ell (t) \pi}{2}$$

$$= \left[\frac{\pi r_o^2}{2} + r_o \ell_o \pi\right](1 - t/t_B)^2$$

The weight of the flare is generally specified in terms of both a total weight (WFO) and a grain weight (WG). The grain weight is changing as a function of time. If it is assumed for simplicity that the grain weight changes with a similar expression as the cross-sectional area, then the expression for the flare weight is as shown in Table 3-17. This table shows the basic computations the simulation uses to determine the flare trajectory. Figure 3-11 shows a flow diagram of the computations of this subroutine including component resolution of all acceleration, velocity, and position components. Table 3-18 contains a listing of this subroutine.

Table 3-17. Drag

Drag accelerations: $1/2\ \rho\ C_D G S_F(k) V^2 / W_V(k)$

1. 2.

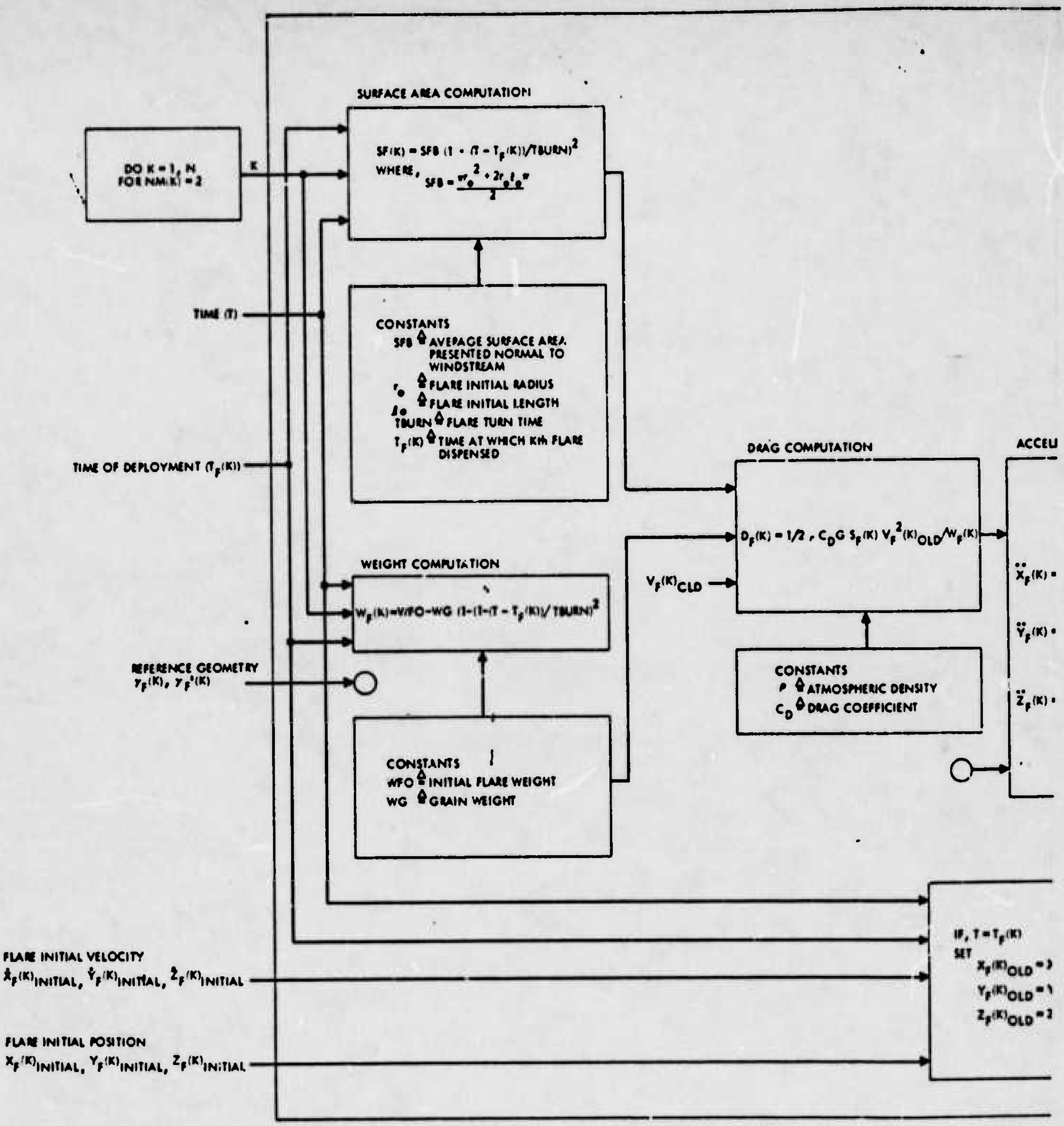
1. $A1 = \pi r_o^2$

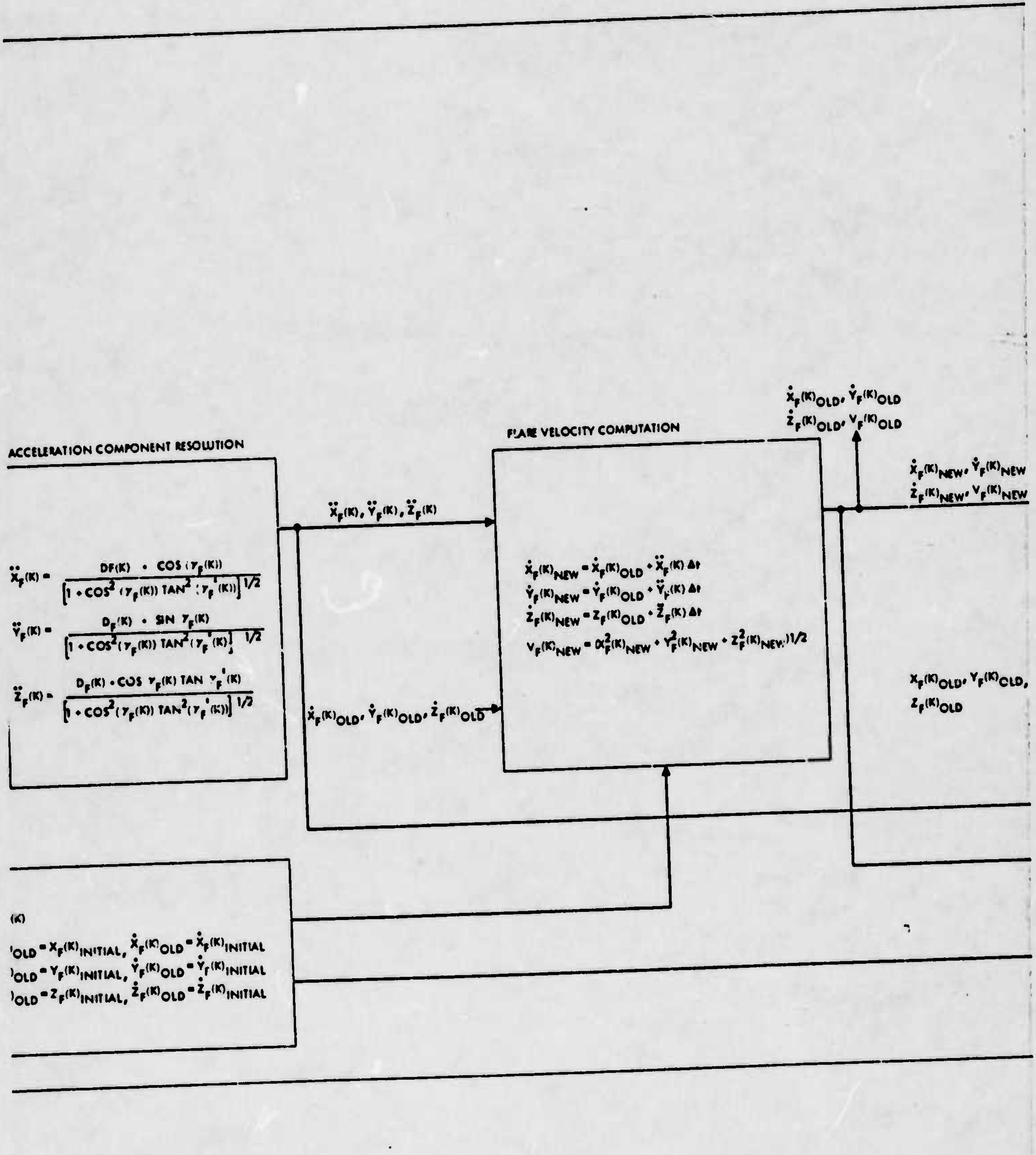
$A2 = 2 r_o \ell_o \pi$

$SFB = (A1 + A2)/2$

$SF(k) = SFB\ (1 - (T - T_F(k)/TBURN)^2$

2. $W_F(k) = WFO - WG\left(1 - (1 - (T - T_F(k))/TBURN)^2\right)$


SURFACE AREA COMPUTATION
SF(K) = SFB (1 - (T - T_F(K))/TBURN)^2
WHERE, SFB = πr_0^2 + 2r_0 l_0 π / 2
DO K = 1, N FOR NM(K) = 2
K
TIME (T)
CONSTANTS
SFB ≙ AVEPAGE SURFACE AREA PRESENTED NORMAL TO WINDSTREAM
r_0 ≙ FLARE INITIAL RADIUS
l_0 ≙ FLARE INITIAL LENGTH
TBURN ≙ FLARE TURN TIME
T_F(K) ≙ TIME AT WHICH Kth FLARE DISPENSED
TIME OF DEPLOYMENT (T_F(K))
DRAG COMPUTATION
ACCEL
D_F(K) = 1/2 ρ C_D G S_F(K) V_F^2(K)_OLD / W_F(K)
V_F(K)_OLD
WEIGHT COMPUTATION
W_F(K) = WFO - WG (1 - (1 - (T - T_F(K))/ TBURN)^2
REFERENCE GEOMETRY
γ_F(K), γ_F'(K)
CONSTANTS
ρ ≙ ATMOSPHERIC DENSITY
C_D ≙ DRAG COEFFICIENT
Ẍ_F(K) =
Ÿ_F(K) =
Z̈_F(K) =
CONSTANTS
WFO ≙ INITIAL FLARE WEIGHT
WG ≙ GRAIN WEIGHT
IF, T = T_F(K)
SET
X_F(K)_OLD = X
Y_F(K)_OLD = Y
Z_F(K)_OLD = Z
FLARE INITIAL VELOCITY
Ẋ_F(K)_INITIAL, Ẏ_F(K)_INITIAL, Ż_F(K)_INITIAL
FLARE INITIAL POSITION
X_F(K)_INITIAL, Y_F(K)_INITIAL, Z_F(K)_INITIAL


ACCELERATION COMPONENT RESOLUTION
$\ddot{X}_F(K) = \frac{DF(K) \cdot COS(\gamma_F(K))}{\left[1 + COS^2(\gamma_F(K))\ TAN^2(\gamma_F'(K))\right]^{1/2}}$
$\ddot{Y}_F(K) = \frac{D_F(K) \cdot SIN\ \gamma_F(K)}{\left[1 + COS^2(\gamma_F(K))\ TAN^2(\gamma_F'(K)\right]^{1/2}}$
$\ddot{Z}_F(K) = \frac{D_F(K) \cdot COS\ \gamma_F(K)\ TAN\ \gamma_F'(K)}{\left[1 + COS^2(\gamma_F(K))\ TAN^2(\gamma_F'(K))\right]^{1/2}}$
$\ddot{X}_F(K), \ddot{Y}_F(K), \ddot{Z}_F(K)$
$\dot{X}_F(K)_{OLD}, \dot{Y}_F(K)_{OLD}, \dot{Z}_F(K)_{OLD}$
FLARE VELOCITY COMPUTATION
$\dot{X}_F(K)_{NEW} = \dot{X}_F(K)_{OLD} + \ddot{X}_F(K)\,\Delta t$
$\dot{Y}_F(K)_{NEW} = \dot{Y}_F(K)_{OLD} + \ddot{Y}_F(K)\,\Delta t$
$\dot{Z}_F(K)_{NEW} = Z_F(K)_{OLD} + \ddot{Z}_F(K)\,\Delta t$
$V_F(K)_{NEW} = (X_F^2(K)_{NEW} + Y_F^2(K)_{NEW} + Z_F^2(K)_{NEW})^{1/2}$
$\dot{X}_F(K)_{OLD}, \dot{Y}_F(K)_{OLD}$
$\dot{Z}_F(K)_{OLD}, V_F(K)_{OLD}$
$\dot{X}_F(K)_{NEW}, \dot{Y}_F(K)_{NEW}$
$\dot{Z}_F(K)_{NEW}, V_F(K)_{NEW}$
$X_F(K)_{OLD}, Y_F(K)_{OLD},$
$Z_F(K)_{OLD}$
(K)
$)_{OLD} = X_F(K)_{INITIAL}, \dot{X}_F(K)_{OLD} = \dot{X}_F(K)_{INITIAL}$
$)_{OLD} = Y_F(K)_{INITIAL}, \dot{Y}_F(K)_{OLD} = \dot{Y}_F(K)_{INITIAL}$
$)_{OLD} = Z_F(K)_{INITIAL}, \dot{Z}_F(K)_{OLD} = \dot{Z}_F(K)_{INITIAL}$

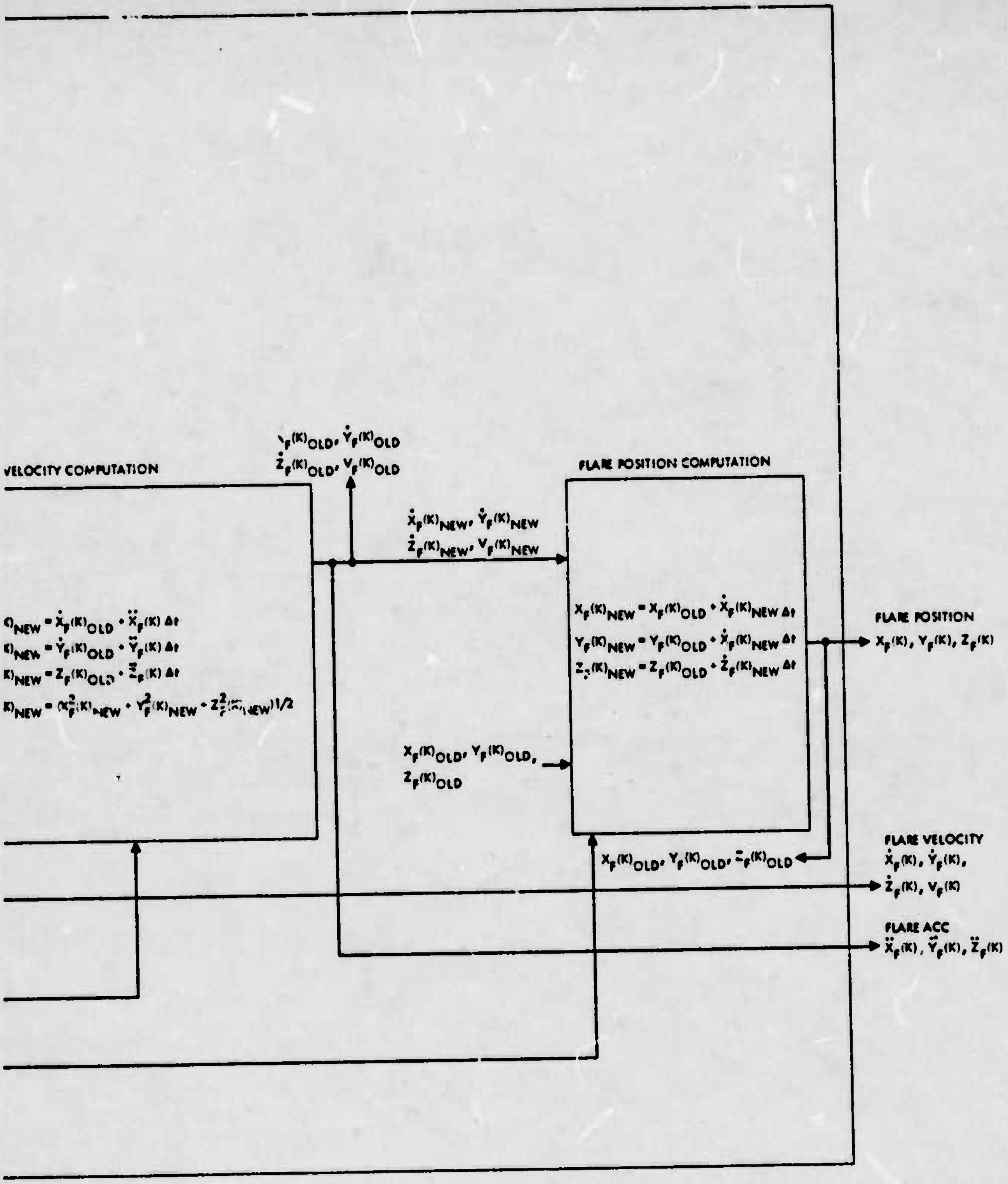

VELOCITY COMPUTATION
$^{)}_{NEW} = \dot{X}_F^{(K)}{}_{OLD} + \ddot{X}_F^{(K)}\,\Delta t$
$^{K)}_{NEW} = \dot{Y}_F^{(K)}{}_{OLD} + \ddot{Y}_F^{(K)}\,\Delta t$
$^{K)}_{NEW} = Z_F^{(K)}{}_{OLD} + \ddot{Z}_F^{(K)}\,\Delta t$
$^{K)}_{NEW} = (X_F^{2}{}^{(K)}{}_{NEW} + Y_F^{2}{}^{(K)}{}_{NEW} + Z_F^{2}{}^{(K)}{}_{NEW})^{1/2}$
$\dot{X}_F^{(K)}{}_{OLD}, \dot{Y}_F^{(K)}{}_{OLD}$
$\dot{Z}_F^{(K)}{}_{OLD}, V_F^{(K)}{}_{OLD}$
$\dot{X}_F^{(K)}{}_{NEW}, \dot{Y}_F^{(K)}{}_{NEW}$
$\dot{Z}_F^{(K)}{}_{NEW}, V_F^{(K)}{}_{NEW}$
$X_F^{(K)}{}_{OLD}, Y_F^{(K)}{}_{OLD},$
$Z_F^{(K)}{}_{OLD}$
FLARE POSITION COMPUTATION
$X_F^{(K)}{}_{NEW} = X_F^{(K)}{}_{OLD} + \dot{X}_F^{(K)}{}_{NEW}\,\Delta t$
$Y_F^{(K)}{}_{NEW} = Y_F^{(K)}{}_{OLD} + \dot{X}_F^{(K)}{}_{NEW}\,\Delta t$
$Z_F^{(K)}{}_{NEW} = Z_F^{(K)}{}_{OLD} + \dot{Z}_F^{(K)}{}_{NEW}\,\Delta t$
$X_F^{(K)}{}_{OLD}, Y_F^{(K)}{}_{OLD}, Z_F^{(K)}{}_{OLD}$
FLARE POSITION
$X_F^{(K)}, Y_F^{(K)}, Z_F^{(K)}$
FLARE VELOCITY
$\dot{X}_F^{(K)}, \dot{Y}_F^{(K)},$
$\dot{Z}_F^{(K)}, V_F^{(K)}$
FLARE ACC
$\ddot{X}_F^{(K)}, \ddot{Y}_F^{(K)}, \ddot{Z}_F^{(K)}$

Figure 3-11. Flare dynamics, Kth flare

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Table 3-18. Flare dynamics subroutine

```
SUBROUTINE FLRDYN      74/74    OPT=1                         FTN 4.2+P381        79/11/79  13.33.59.

                    SUBROUTINE FLRDYN(T,DELT,TF,TAURN,SF,SF0,XFL,WF0,WG,WF,N,RHO,CDF    MPR19       01
                   +,G,VF,X,XP,XFD,XF,XFP,NN,NC)                                        FLRDYNAM     3
                    DIMENSION X(10),XP(10),NN(20),TF(20),WF(20),VF(20)                  FLRDYNAM     4
                    DIMENSION XFD(10,20),XF(10,20),XFP(10,20),SF(20)                    FLRDYNAM     5
                    DO 1 K=1,N                                                          FLRDYNAM     6
                    GO TO (2,5,2), NN(K)                                                FLRDYNAM     7
                  5 IF(XFP(9,K).LE.0.) GO TO 1                                          FLRDYNAM     8
                    A=1.-(T-TF(K))/TAURN                                                FLRDYNAM     9
                    SF(K)=SF0*A*A                                                       FLRDYNAM    10
                    GO TO (17,17,17,18), NC                                             FLRDYNAM    11
                 18 A1=SF0/3.                                                           FLRDYNAM    12
                    A2=XFL*XFL/144.                                                     FLRDYNAM    13
                    AREA=(A1+A2)/2.                                                     FLRDYNAM    14
                    SFK=AREA*A*A                                                        FLRDYNAM    15
                    WF(K)=WF0*A*A*A                                                     FLRDYNAM    16
                    GO TO 19                                                            FLRDYNAM    17
                 17 SFK=SF(K)                                                           FLRDYNAM    18
                    WF(K)=WF0-WG*(1.-A*A)                                               FLRDYNAM    19
                 19 CONST=-.5*RHO*CDF*G                                                 FLRDYNAM    20
                    DF=CONST*SFK*VF(K)*VF(K)/WF(K)                                      FLRDYNAM    21
                    TANGFP=XFP(9,K)/XF(7,K)                                             FLRDYNAM    22
                    B=SQRT(XF(7,K)*XF(7,K)+XF(9,K)*XF(9,K))                             FLRDYNAM    23
                    COSGF=XF(7,K)/B                                                     FLRDYNAM    24
                    SINGF=XF(9,K)/B                                                     FLRDYNAM    25
                    A=COSGF*COSGF*TANGFP*TANGFP                                         FLRDYNAM    26
                    XFD(1,K)=DF*COSGF/SQRT(1.+A)                                        FLRDYNAM    27
                    XFD(2,K)=DF*SINGF/SQRT(1.+A)                                        FLRDYNAM    28
                    XFD(3,K)=DF*COSGF*TANGFP/SQRT(1.+A)-G                               FLRDYNAM    29
                    DO 3 IV=1,6                                                         FLRDYNAM    30
                    XF(IV,K)=X(IV)                                                      FLRDYNAM    31
                  3 XFP(IV,K)=XP(IV)                                                    FLRDYNAM    32
                    XFP(6,K)=XFP(6,K)+XF(7,K)*DELT                                      FLRDYNAM    33
                    XFP(7,K)=XFP(7,K)+XFD(1,K)*DELT                                     FLRDYNAM    34
                    XF(7,K)=XF(7,K)+XFD(1,K)*DELT                                       FLRDYNAM    35
                    XF(9,K)=XF(9,K)+XFD(2,K)*DELT                                       FLRDYNAM    36
                    XFP(9,K)=XFP(9,K)+XFD(3,K)*DELT                                     FLRDYNAM    37
                    VF(K)=SQRT(XF(7,K)*XF(7,K)+XF(9,K)*XF(9,K)+XFP(9,K)*XFP(9,K))       FLRDYNAM    38
                    XF(6,K)=XF(6,K)+XF(7,K)*DELT                                        FLRDYNAM    39
                    XF(8,K)=XF(8,K)+XF(9,K)*DELT                                        FLRDYNAM    40
                    XFP(8,K)=XFP(8,K)+XFP(9,K)*DELT                                     FLRDYNAM    41
                  1 CONTINUE                                                            FLRDYNAM    42
                  2 RETURN                                                              FLRDYNAM    43
                    END                                                                 FLRDYNAM    44
```

4. ANGLE AND RANGE COMPUTATIONS

In this section, the missile and target and missile and flare computations are performed to determine angle, angle rate, range, and range rate. Section 4. 1 discusses the angle computations, and Section 4. 2 discusses the range computations.

4. 1 ANGLE AND ANGLE RATE COMPUTATIONS

Tables 4-1 and 4-2 show how the angles between the missile and target and their corresponding rates shown in the geometry are computed along with the variable name associated with each in the computer program. Subroutine MTGTANG in the program is responsible for performing these computations. See Table 4-3 for a listing of this subroutine. Figures 4-1 and 4-2 show the computational procedures for these calculations in block diagram form.

Figures 4-3 and 4-4 describe the angles and angular computations for the angles between the missile and flare (Kth flare). Subroutine MFLANG is used to compute these angular variables. See Table 4-4 for a program listing.

Table 4-1. Angle and angle rate computations between target and missile, horizontal plane

Angle/ Angle Rate	Variable Name	Computation
σ	Z(1)	$TAN^{-1}[X(3)/X(1)]$
$\dot{\sigma}$	Z(2)	$[X(1)*X(4)-X(2)*X(3)]/[X(3)*X(3)+X(1)*X(1)]$
ψ	Z(3)	$TAN^{-1}\Big[[X(8)-X(3)]/[X(6)-X(1)]\Big]$
$\dot{\psi}$	Z(4)	$[X(6)-X(1)]*[X(9)-X(4)]-[X(8)-X(3)]*[X(7)-X(2)]/\Big[[X(6)-X(1)]^2+[X(8)-X(3)]^2\Big]$
γ	Z(5)	$TAN^{-1}[X(4)/X(2)]$
$\dot{\gamma}$	Z(6)	$[\dot{X}(4)*X(2)-X(4)*\dot{X}(2)]/[X(2)*X(2)+X(4)*X(4)]$
γ_T	Z(7)	$TAN^{-1}[X(9)/X(7)]$
$\dot{\gamma}_T$	Z(8)	$[\dot{X}(9)*X(7)-\dot{X}(7)*X(9)]/[X(7)*X(7)+X(9)*X(9)]$
$\gamma-\sigma$	Z(9)	$Z(5)-Z(1)$
σ_T	Z(10)	$TAN^{-1}[X(8)/X(6)]$
σ_T	Z(11)	$[X(6)*X(9)-X(7)*X(8)]/[X(6)*X(6)+X(8)*X(8)]$
$\alpha+\gamma-\psi$	Z(12)	$ALPHA+Z(5)-Z(3)$

Table 4-2. Angle and angle rate computations between target and missile, vertical plane

Angle/ Angle Rate	Variable Name	Computation
σ'	ZP(1)	TAN^{-1}[XP(3)/XP(1)]
$\dot{\sigma}'$	ZP(2)	[XP(1)*XP(4)-XP(2)*XP(3)]/[XP(3)*XP(3)+XP(1)*XP(1)]
ψ'	ZP(3)	TAN^{-1}[XP(8)-XP(3)]/[XP(6)-XP(1)]]
$\dot{\psi}'$	ZP(4)	[XP(6)-XP(1)]*[XP(9)-XP(4)]-[XP(8)-XP(3)]*[XP(7)-XP(2)]/ [[XP(6)-XP(1)]^2+[XP(8)-XP(3)]^2]
γ'	ZP(5)	TAN^{-1}[XP(4)/XP(2)]
γ'	ZP(6)	[$\dot{\text{X}}$P(4)*XP(2)-XP(4)*$\dot{\text{X}}$P(2)]/[XP(2)*XP(2)+XP(4)*XP(4)]
γ_T'	ZP(7)	TAN^{-1}[XP(9)/XP(7)]
$\dot{\gamma}_T'$	ZP(8)	[$\dot{\text{X}}$P(9)*XP(7)-$\dot{\text{X}}$P(7)*XP(9)]/[XP(7)*XP(7)+XP(9)*XP(9)]
$\gamma'-\sigma'$	ZP(9)	ZP(5)-ZP(1)
σ_T'	ZP(10)	TAN^{-1}[XP(8)/XP(6)]
$\dot{\sigma}_T'$	ZP(11)	[XP(6)*XP(9)-XP(7)*XP(8)]/[XP(6)*XP(6)+XP(8)*XP(8)]
$\alpha'+\gamma'-\psi'$	ZP(12)	ALPHAP+ZP(5)-ZP(3)

Table 4-3. Missile and target angle and angle rate computations subroutines

```
SUBROUTINE MTGTANG      74/74    OPT=1                          FTN 4.2+P380        05/01/75  13.31.14.

             SUBROUTINE MTGTANG(X,ALPHA,X40,X20,X90,X70,Z,PI)                         MAR19     77
             DIMENSION X(10),Z(14)                                                    MISSTGTA   3
             IF(X(1).NE.0.) GO TO 1                                                   MISSTGTA   4
             Z(1)=PI/2.                                                               MISSTGTA   5
             GO TO 2                                                                  MISSTGTA   6
           1 Z(1)=ATAN2(X(3),X(1))                                                    MISSTGTA   7
          2  Z(2)=X(3)**2+X(1)**2                                                     MAR20     18
             IF(Z(2).NE.0.0) Z(2)=(X(1)*X(4)-X(2)*X(3))/Z(2)                          MAR24     19
             Y=X(8)-X(3)                                                              MISSTGTA   9
             XX=X(6)-X(1)                                                             MISSTGTA  10
             IF(XX.NE.0.) GO TO 3                                                     MISSTGTA  11
             Z(3)=PI/2.                                                               MISSTGTA  12
             GO TO 4                                                                  MISSTGTA  13
           3 Z(3)=ATAN2(Y,XX)                                                         MISSTGTA  14
             IF(Z(3).GE.-PI/2.) GO TO 4                                               MISSTGTA  15
             Z(3)=2.*PI+Z(3)                                                          MISSTGTA  16
           4 D1=X(6)-X(1)                                                             MISSTGTA  17
             D2=X(8)-X(3)                                                             MISSTGTA  18
             Z(4)=((X(6)-X(1))*(X(9)-X(4))-(X(8)-X(3))*(X(7)-X(2)))/(D1*D1+D2*D MISSTGTA  19
            +2)                                                                       MISSTGTA  20
             IF(X(2).NE.0.) GO TO 5                                                   MISSTGTA  21
             Z(5)=PI/2.                                                               MISSTGTA  22
             GO TO 6                                                                  MISSTGTA  23
           5 Z(5)=ATAN2(X(4),X(2))                                                    MISSTGTA  24
           6 Z(6)=(X40*X(2)-X(4)*X20)/(X(2)*X(2)+X(4)*X(4))                           MISSTGTA  25
             IF(X(9).NE.0.) GO TO 11                                                  MISSTGTA  26
             Z(7)=0.                                                                  MISSTGTA  27
             GO TO 8                                                                  MISSTGTA  28
          11 IF(X(7).NE.0.) GO TO 7                                                   MISSTGTA  29
             Z(7)=PI/2.                                                               MISSTGTA  30
             GO TO 8                                                                  MISSTGTA  31
           7 Z(7)=ATAN2(X(9),X(7))                                                    MISSTGTA  32
           8 Z(8)=(X90*X(7)-X70*X(9))/(X(7)*X(7)+X(9)*X(9))                           MISSTGTA  33
             Z(9)=Z(5)-Z(1)                                                           MISSTGTA  34
             IF(X(6).NE.0.) GO TO 9                                                   MISSTGTA  35
             Z(10)=PI/2.                                                              MISSTGTA  36
             GO TO 10                                                                 MISSTGTA  37
           9 Z(10)=ATAN2(X(8),X(6))                                                   MISSTGTA  38
          10 Z(11)=(X(6)*X(9)-X(7)*X(8))/(X(6)*X(6)+X(8)*X(8))                        MISSTGTA  39
             Z(12)=ALPHA+Z(5)-Z(3)                                                    MISSTGTA  40
             RETURN                                                                   MISSTGTA  41
             END                                                                      MISSTGTA  42
```

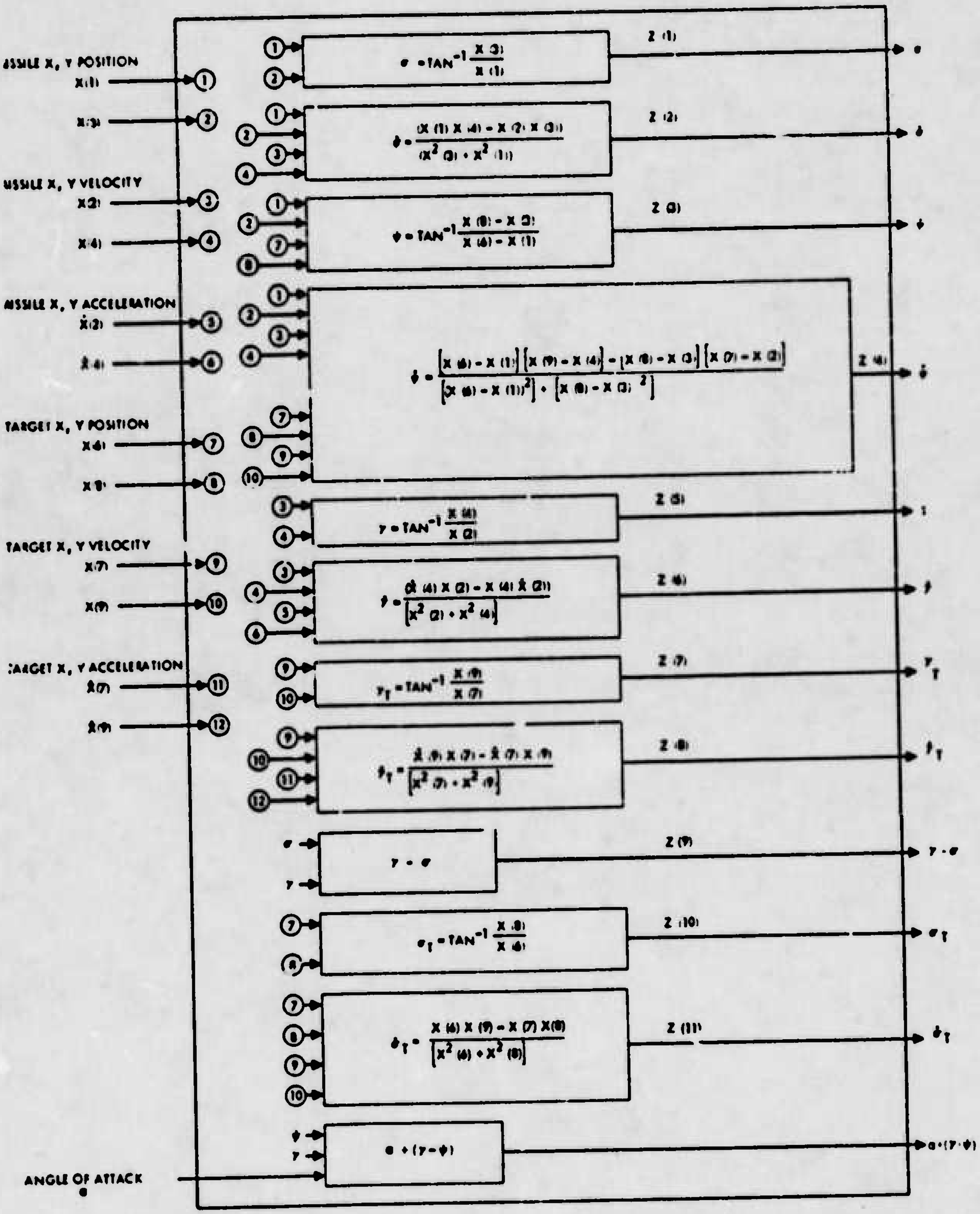
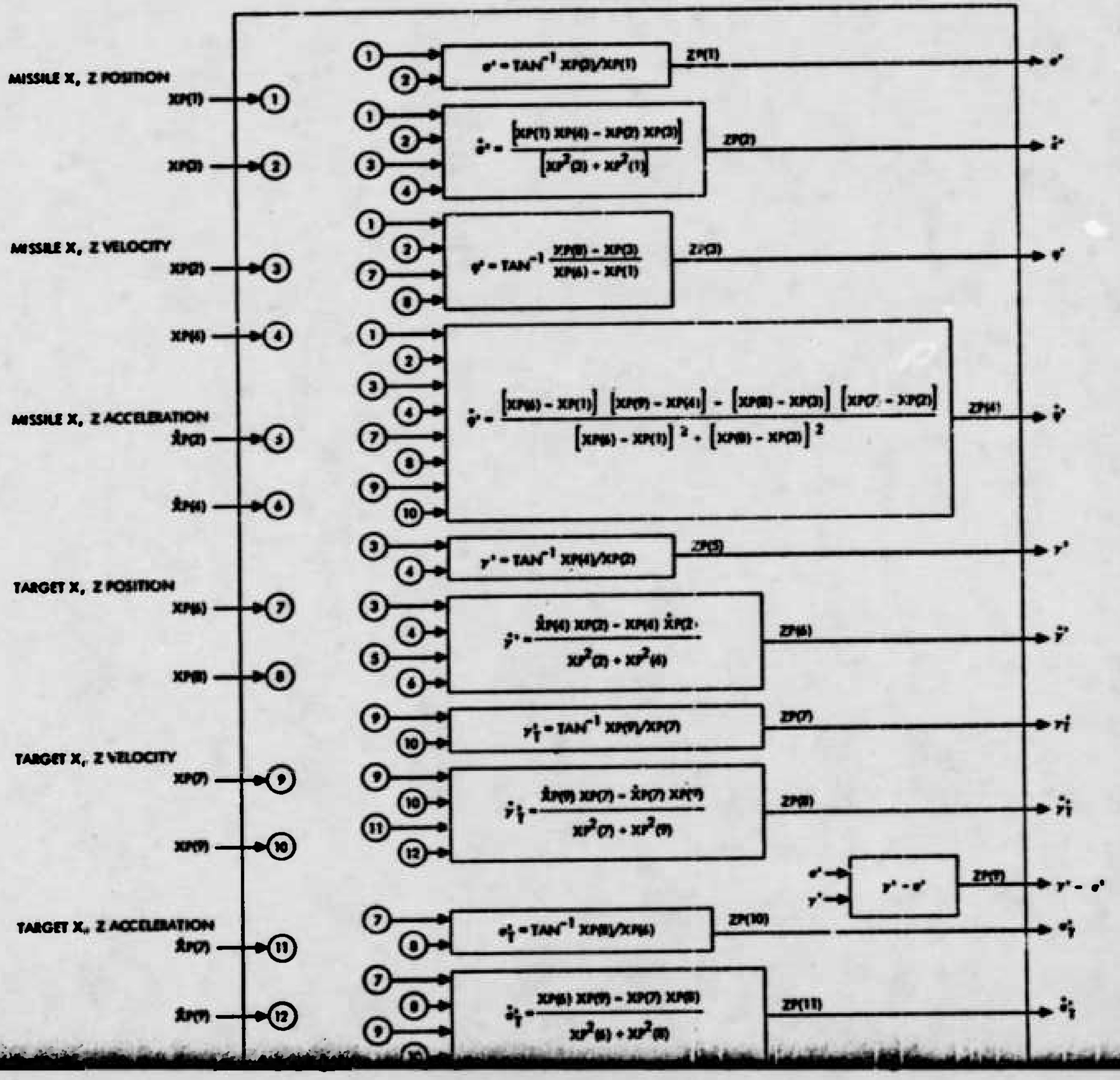


Figure 4-1. Missile and target angle computations, horizontal plane


MISSILE X, Z POSITION
XP(1)
XP(2)
MISSILE X, Z VELOCITY
XP(3)
XP(4)
MISSILE X, Z ACCELERATION
$\dot{X}P(2)$
$\dot{X}P(4)$
TARGET X, Z POSITION
XP(6)
XP(8)
TARGET X, Z VELOCITY
XP(7)
XP(9)
TARGET X, Z ACCELERATION
$\dot{X}P(7)$
$\dot{X}P(9)$
$\sigma' = TAN^{-1}\ XP(2)/XP(1)$
ZP(1)
σ'
$\dot{\sigma}' = \frac{[XP(1)\ XP(4) - XP(2)\ XP(3)]}{[XP^2(2) + XP^2(1)]}$
ZP(2)
$\dot{\sigma}'$
$\psi' = TAN^{-1}\ \frac{XP(8) - XP(3)}{XP(6) - XP(1)}$
ZP(3)
ψ'
$\dot{\psi}' = \frac{[XP(6) - XP(1)]\ [XP(9) - XP(4)] - [XP(8) - XP(3)]\ [XP(7) - XP(2)]}{[XP(6) - XP(1)]^2 + [XP(8) - XP(3)]^2}$
ZP(4)
$\dot{\psi}'$
$\gamma' = TAN^{-1}\ XP(4)/XP(2)$
ZP(5)
γ'
$\dot{\gamma}' = \frac{\dot{X}P(4)\ XP(2) - XP(4)\ \dot{X}P(2)}{XP^2(2) + XP^2(4)}$
ZP(6)
$\dot{\gamma}'$
$\gamma_T' = TAN^{-1}\ XP(9)/XP(7)$
ZP(7)
γ_T'
$\dot{\gamma}_T' = \frac{\dot{X}P(9)\ XP(7) - \dot{X}P(7)\ XP(9)}{XP^2(7) + XP^2(9)}$
ZP(8)
$\dot{\gamma}_T'$
σ'
γ'
$\gamma' - \sigma'$
ZP(9)
$\gamma' - \sigma'$
$\sigma_T' = TAN^{-1}\ XP(8)/XP(6)$
ZP(10)
σ_T'
$\dot{\sigma}_T' = \frac{XP(6)\ XP(9) - XP(7)\ XP(8)}{XP^2(6) + XP^2(8)}$
ZP(11)
$\dot{\sigma}_T'$
1
2
3
4
5
6
7
8
9
10
11
12

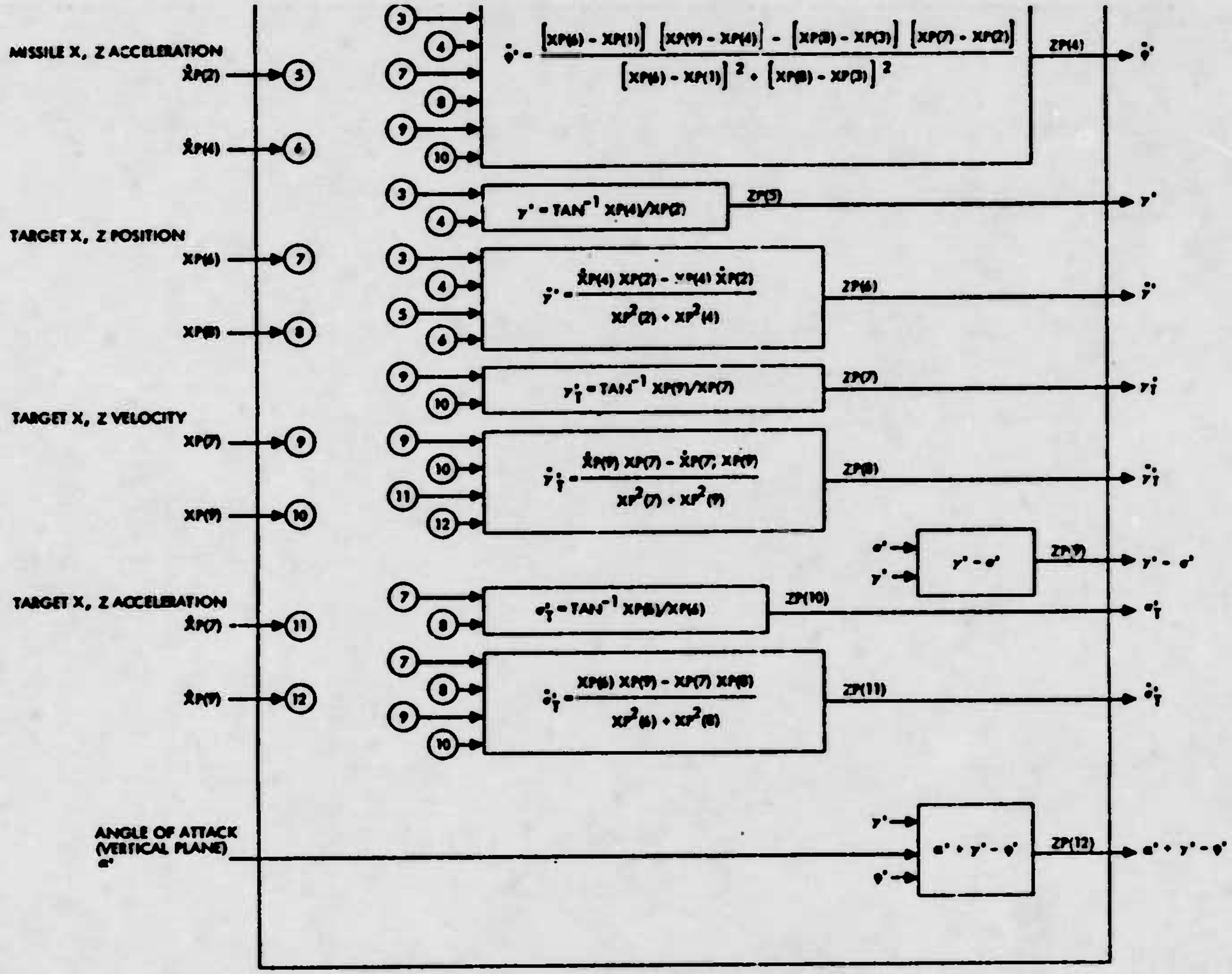
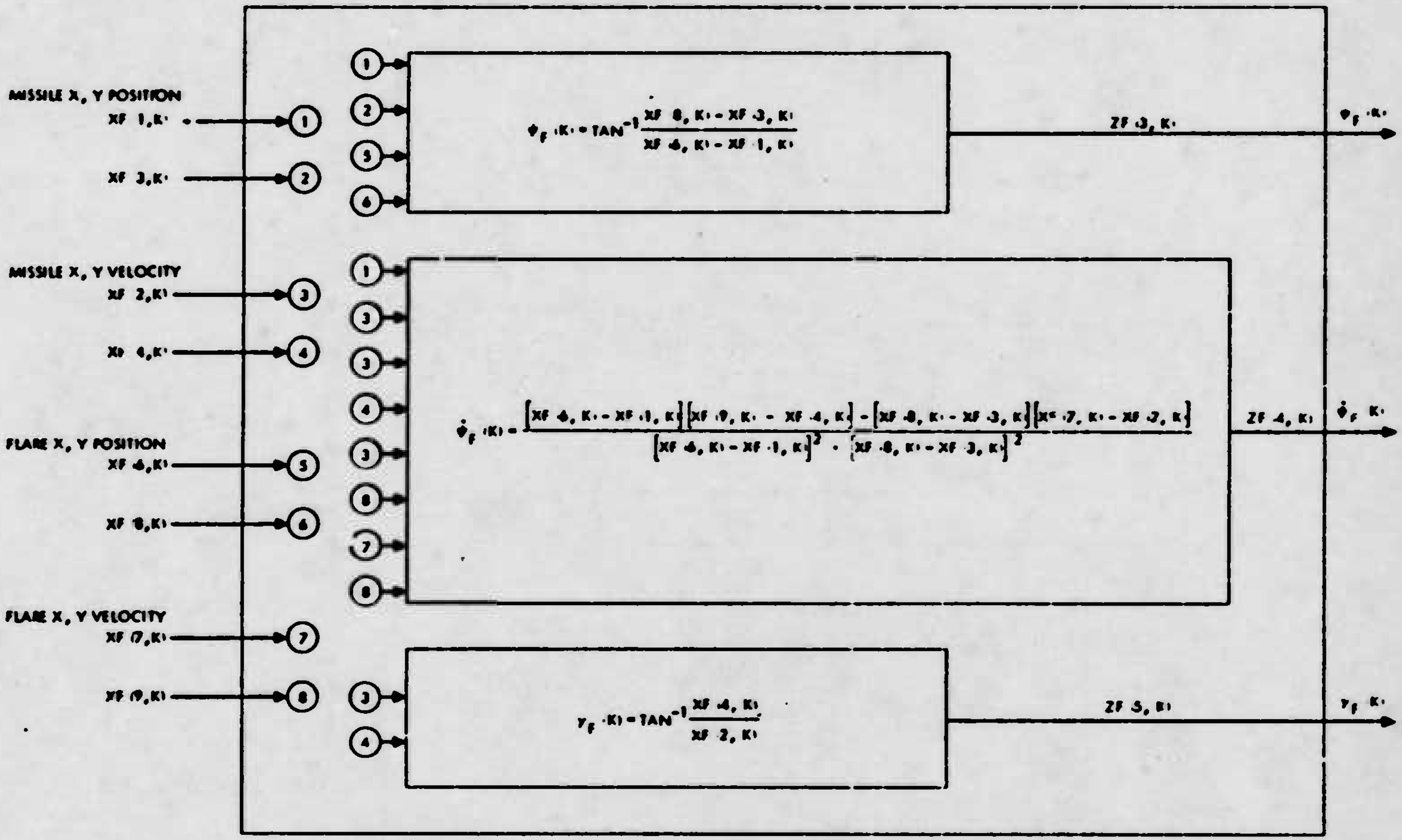

MISSILE X, Z ACCELERATION
Ẍ P(2)
Ẍ P(4)
TARGET X, Z POSITION
XP(6)
XP(8)
TARGET X, Z VELOCITY
XP(7)
XP(9)
TARGET X, Z ACCELERATION
Ẍ P(7)
Ẍ P(9)
ANGLE OF ATTACK (VERTICAL PLANE) α'
3 4 7 8 9 10 11 12
φ̈' = {[XP(6) - XP(1)] [XP(9) - XP(4)] - [XP(8) - XP(3)] [XP(7) - XP(2)]} / {[XP(6) - XP(1)]² + [XP(8) - XP(3)]²}
ZP(4) φ̇'
γ' = TAN⁻¹ XP(4)/XP(2)
ZP(5) γ'
γ̇' = [Ẋ P(4) XP(2) - XP(4) Ẋ P(2)] / [XP²(2) + XP²(4)]
ZP(6) γ̇'
γ'_T = TAN⁻¹ XP(9)/XP(7)
ZP(7) γ'_T
γ̇'_T = [Ẋ P(9) XP(7) - Ẋ P(7) XP(9)] / [XP²(7) + XP²(9)]
ZP(8) γ̇'_T
σ' γ' γ' - σ'
ZP(9) γ' - σ'
σ'_T = TAN⁻¹ XP(8)/XP(6)
ZP(10) σ'_T
σ̇'_T = [XP(6) XP(9) - XP(7) XP(8)] / [XP²(6) + XP²(8)]
ZP(11) σ̇'_T
γ' φ' α' + γ' - φ'
ZP(12) α' + γ' - φ'

Figure 4-2. Missile and target angle computations, vertical plane


MISSILE X, Y POSITION
XF (1,K)
XF (3,K)
MISSILE X, Y VELOCITY
XF (2,K)
XF (4,K)
FLARE X, Y POSITION
XF (6,K)
XF (8,K)
FLARE X, Y VELOCITY
XF (7,K)
XF (9,K)
1
2
3
4
5
6
7
8
1
2
3
6
1
3
3
4
3
8
7
8
3
4
$\psi_f(K) = \tan^{-1}\frac{XF(8,K) - XF(3,K)}{XF(6,K) - XF(1,K)}$
ZF (3, K)
$\psi_f(K)$
$\dot{\psi}_f(K) = \frac{[XF(6,K) - XF(1,K)][XF(9,K) - XF(4,K)] - [XF(8,K) - XF(3,K)][XF(7,K) - XF(2,K)]}{[XF(6,K) - XF(1,K)]^2 + [XF(8,K) - XF(3,K)]^2}$
ZF (4, K)
$\dot{\psi}_f(K)$
$\gamma_f(K) = \tan^{-1}\frac{XF(4,K)}{XF(2,K)}$
ZF (5, K)
$\gamma_f(K)$

Fi_ure 4-3. Missile and flare angle computations, horizontal plane

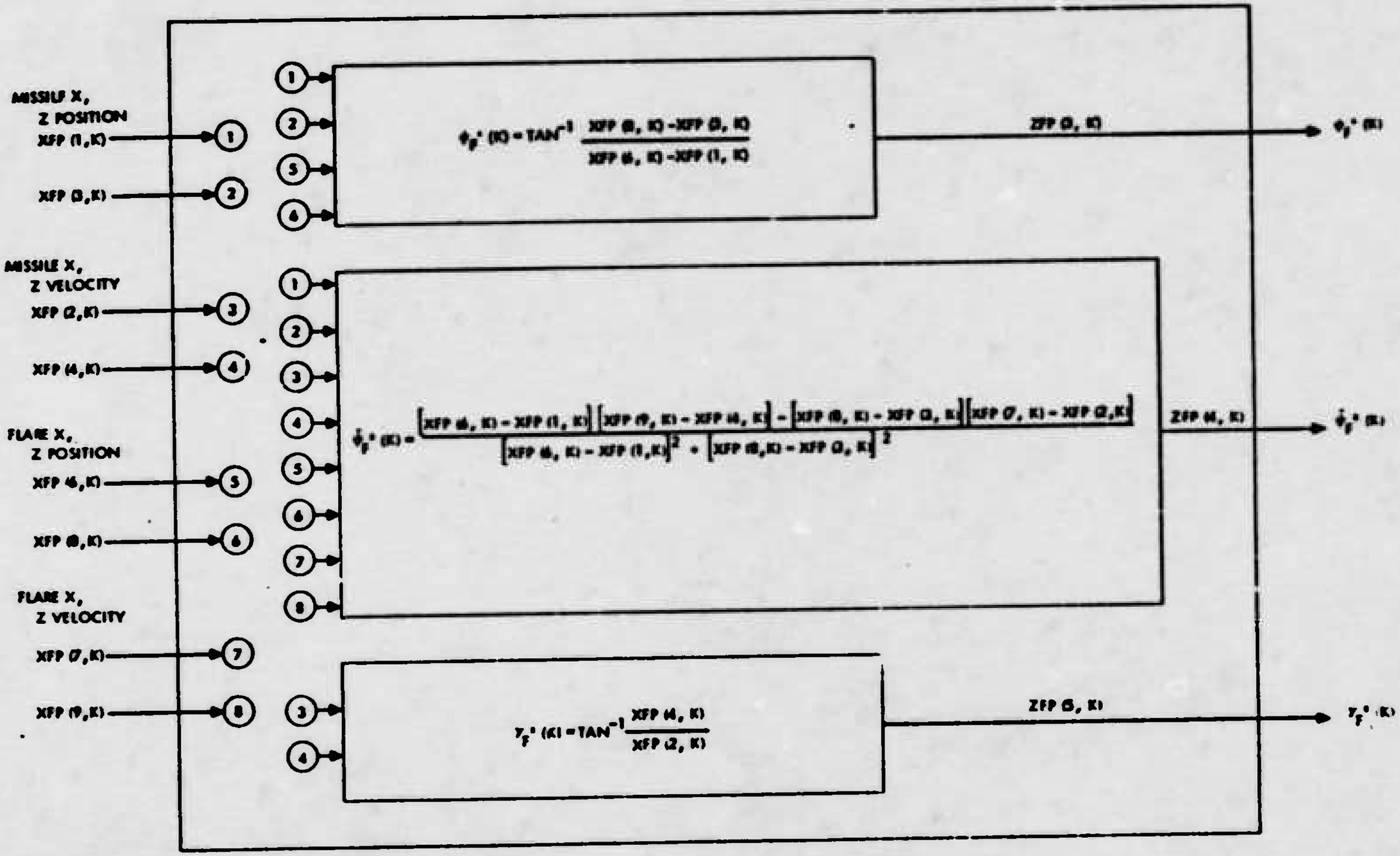
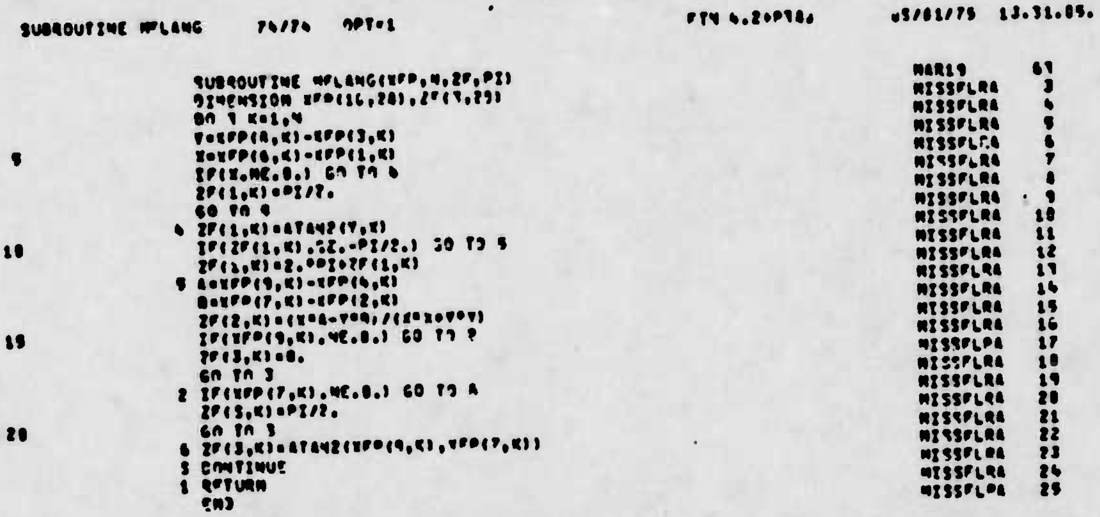

MISSILE X,
Z POSITION
XFP (1,K)
XFP (3,K)
MISSILE X,
Z VELOCITY
XFP (2,K)
XFP (4,K)
FLARE X,
Z POSITION
XFP (6,K)
XFP (8,K)
FLARE X,
Z VELOCITY
XFP (7,K)
XFP (9,K)
1
2
3
4
5
6
7
8
φF' (K) = TAN-1 [XFP (8, K) - XFP (3, K)] / [XFP (6, K) - XFP (1, K)]
ZFP (3, K)
φF' (K)
φ̇F' (K) = {[XFP (6, K) - XFP (1, K)] [XFP (9, K) - XFP (4, K)] - [XFP (8, K) - XFP (3, K)] [XFP (7, K) - XFP (2, K)]} / {[XFP (6, K) - XFP (1, K)]² + [XFP (8, K) - XFP (3, K)]²}
ZFP (4, K)
φ̇F' (K)
γF' (K) = TAN-1 XFP (4, K) / XFP (2, K)
ZFP (5, K)
γF' (K)

Figure 4-4. Missile and flare angle computations, vertical plane

Table 4-4. Missile and flare angle and angle rate computations subroutine



```
SUBROUTINE MFLANG      74/74   OPT=1                             FTN 4.2+P380        05/01/75  13.31.05.

                    SUBROUTINE MFLANG(XFP,N,ZF,PI)                                   MARI9        61
                    DIMENSION XFP(16,28),ZF(3,28)                                    MISSFLRA      3
                    DO 1 K=1,N                                                       MISSFLRA      4
                    Y=XFP(8,K)-XFP(3,K)                                              MISSFLRA      5
                    X=XFP(6,K)-XFP(1,K)                                              MISSFLRA      6
                    IF(X.NE.0.) GO TO 6                                              MISSFLRA      7
                    ZF(1,K)=PI/2.                                                    MISSFLRA      8
                    GO TO 5                                                          MISSFLRA      9
                  6 ZF(1,K)=ATAN2(Y,X)                                               MISSFLRA     10
                    IF(ZF(1,K).GE.-PI/2.) GO TO 5                                    MISSFLRA     11
                    ZF(1,K)=2.*PI+ZF(1,K)                                            MISSFLRA     12
                  5 A=XFP(9,K)-XFP(4,K)                                              MISSFLRA     13
                    B=XFP(7,K)-XFP(2,K)                                              MISSFLRA     14
                    ZF(2,K)=(X*A-Y*B)/(X*X+Y*Y)                                      MISSFLRA     15
                    IF(XFP(9,K).NE.0.) GO TO 2                                       MISSFLRA     16
                    ZF(3,K)=0.                                                       MISSFLRA     17
                    GO TO 3                                                          MISSFLRA     18
                  2 IF(XFP(7,K).NE.0.) GO TO 8                                       MISSFLRA     19
                    ZF(3,K)=PI/2.                                                    MISSFLRA     20
                    GO TO 3                                                          MISSFLRA     21
                  8 ZF(3,K)=ATAN2(XFP(9,K),XFP(7,K))                                 MISSFLRA     22
                  3 CONTINUE                                                         MISSFLRA     23
                  1 RETURN                                                           MISSFLRA     24
                    END                                                              MISSFLRA     25
```

4.2 RANGE AND RANGE RATE COMPUTATIONS

Figure 4-5 shows the computational procedure for determining the missile velocity missile acceleration, missile mach number, the target velocity, target acceleration, the components of relative position velocity and acceleration between the missile and the target, and the relative range and range rate. In addition to these computations, this subroutine also calculates the miss distance and time-to-go parameters. There is a check in the computations to determine if the range rate is postive after missile thrusting is terminated. This thrusting termination period is nominally set at 5 seconds. If this constraint is violated, the program goes into an abort. Tables 4-5 and 4-6 contain listings of these subroutines.

Figure 4-6 shows how the range between the missile and an arbitrary flare (K^{th} flare) as well as their corresponding rates are computed.

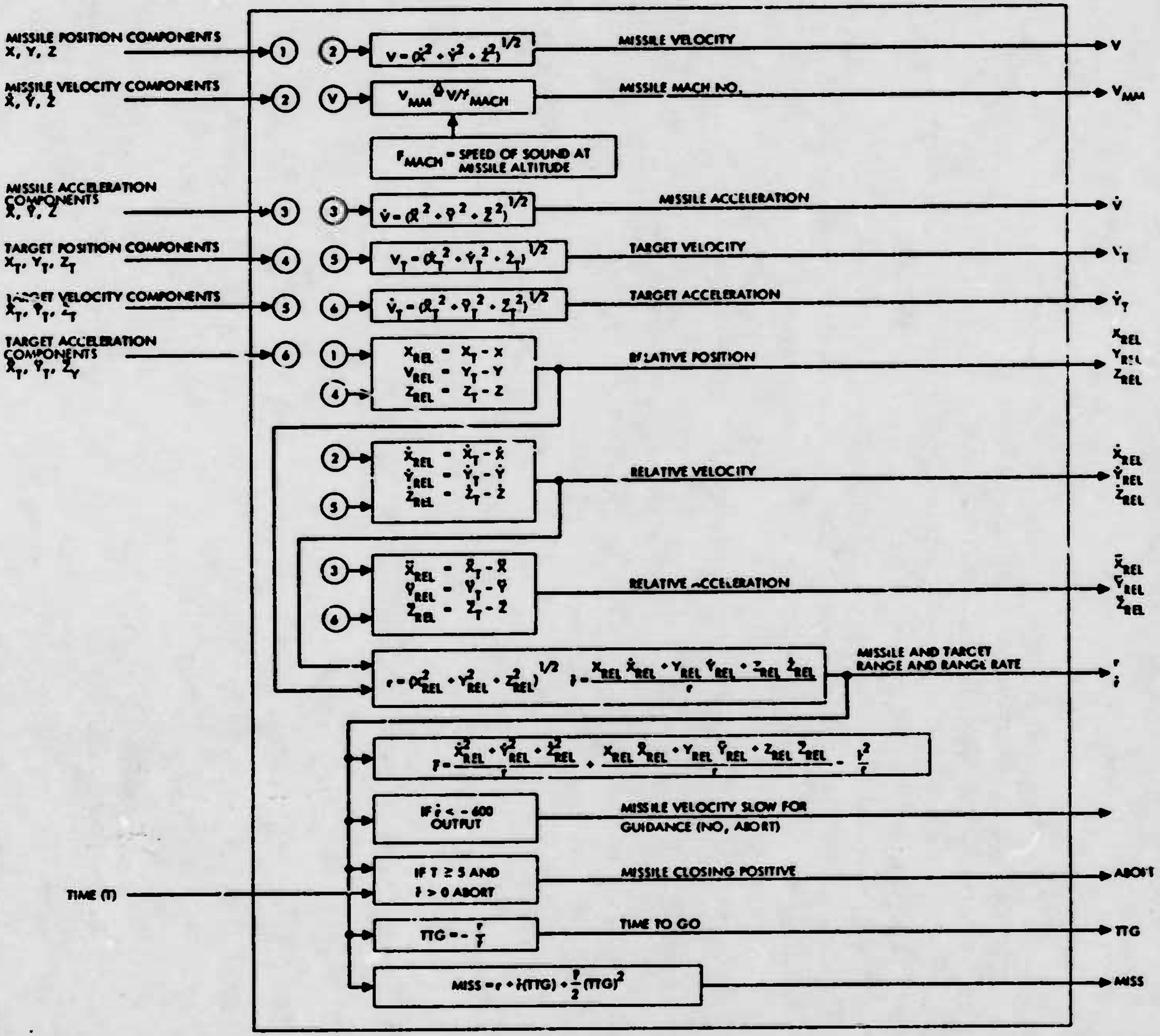

MISSILE POSITION COMPONENTS X, Y, Z
MISSILE VELOCITY COMPONENTS Ẋ, Ẏ, Ż
MISSILE ACCELERATION COMPONENTS Ẍ, Ÿ, Z̈
TARGET POSITION COMPONENTS X_T, Y_T, Z_T
TARGET VELOCITY COMPONENTS Ẋ_T, Ẏ_T, Ż_T
TARGET ACCELERATION COMPONENTS Ẍ_T, Ÿ_T, Z̈_T
TIME (T)
1
2
3
4
5
6
V
V = (Ẋ² + Ẏ² + Ż²)^1/2
V_MM ≜ V/V_MACH
V_MACH = SPEED OF SOUND AT MISSILE ALTITUDE
V̇ = (Ẍ² + Ÿ² + Z̈²)^1/2
V_T = (Ẋ_T² + Ẏ_T² + Ż_T²)^1/2
V̇_T = (Ẍ_T² + Ÿ_T² + Z̈_T²)^1/2
X_REL = X_T - X
Y_REL = Y_T - Y
Z_REL = Z_T - Z
Ẋ_REL = Ẋ_T - Ẋ
Ẏ_REL = Ẏ_T - Ẏ
Ż_REL = Ż_T - Ż
Ẍ_REL = Ẍ_T - Ẍ
Ÿ_REL = Ÿ_T - Ÿ
Z̈_REL = Z̈_T - Z̈
r = (X_REL² + Y_REL² + Z_REL²)^1/2   ṙ = (X_REL Ẋ_REL + Y_REL Ẏ_REL + Z_REL Ż_REL)/r
r̈ = (Ẋ_REL² + Ẏ_REL² + Ż_REL²)/r + (X_REL Ẍ_REL + Y_REL Ÿ_REL + Z_REL Z̈_REL)/r - ṙ²/r
IF ṙ < - 600 OUTPUT
IF T ≥ 5 AND ṙ > 0 ABORT
TTG = - r/ṙ
MISS = r + ṙ(TTG) + r̈/2 (TTG)²
MISSILE VELOCITY
MISSILE MACH NO.
MISSILE ACCELERATION
TARGET VELOCITY
TARGET ACCELERATION
RELATIVE POSITION
RELATIVE VELOCITY
RELATIVE ACCELERATION
MISSILE AND TARGET RANGE AND RANGE RATE
MISSILE VELOCITY SLOW FOR GUIDANCE (NO, ABORT)
MISSILE CLOSING POSITIVE
TIME TO GO
V
V_MM
V̇
V_T
V̇_T
X_REL Y_REL Z_REL
Ẋ_REL Ẏ_REL Ż_REL
Ẍ_REL Ÿ_REL Z̈_REL
r ṙ
ABORT
TTG
MISS

Figure 4·5. Missile and target range and velocity computations

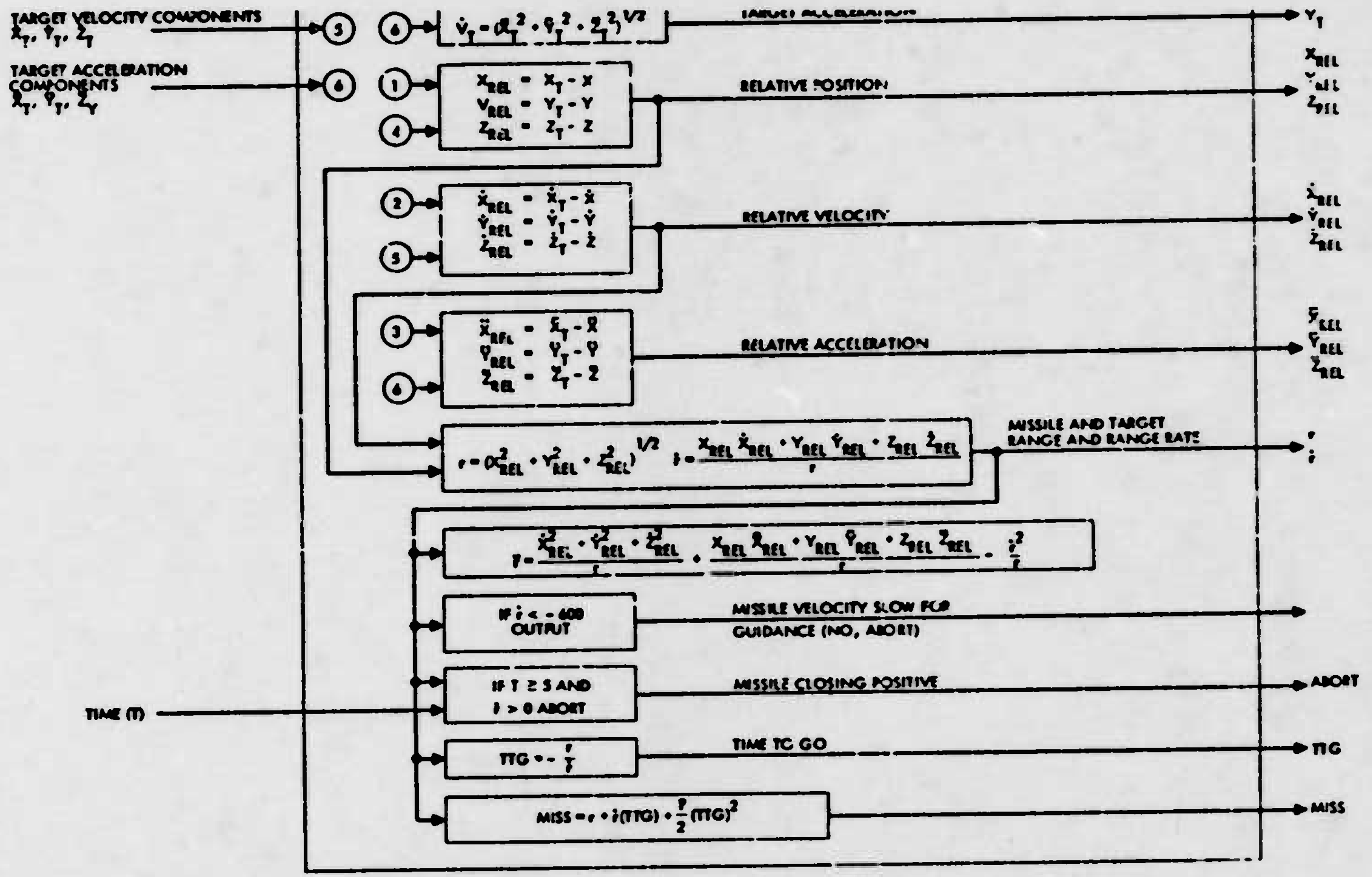
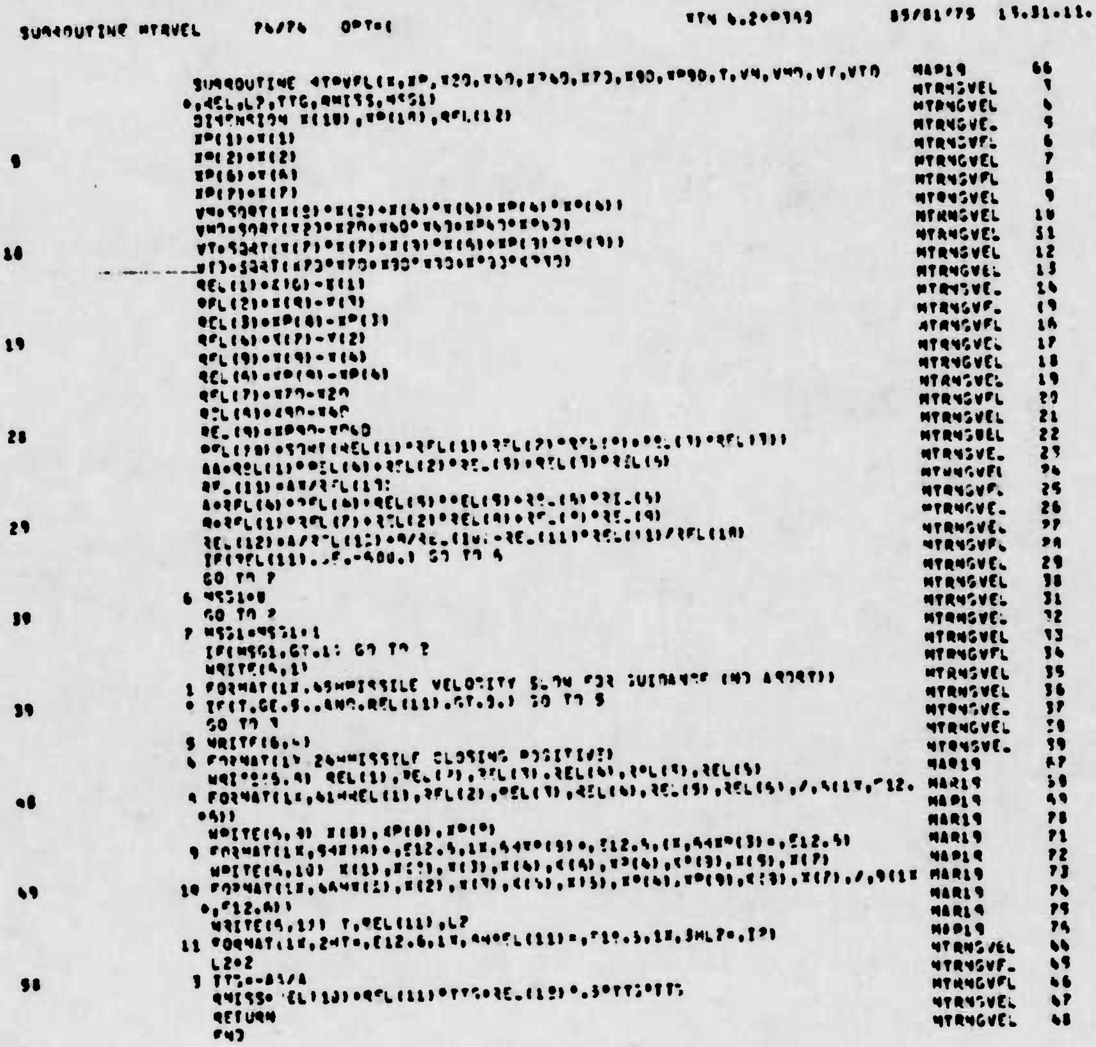

TARGET VELOCITY COMPONENTS
$\dot{X}_T, \dot{Y}_T, \dot{Z}_T$
TARGET ACCELERATION COMPONENTS
$\ddot{X}_T, \ddot{Y}_T, \ddot{Z}_T$
TIME (T)
3
6
1
4
2
5
3
6
$\dot{V}_T = (\ddot{X}_T^2 + \ddot{Y}_T^2 + \ddot{Z}_T^2)^{1/2}$
TARGET ACCELERATION
$\dot{V}_T$
$X_{REL} = X_T - X$
$Y_{REL} = Y_T - Y$
$Z_{REL} = Z_T - Z$
RELATIVE POSITION
X_{REL}
Y_{REL}
Z_{REL}
$\dot{X}_{REL} = \dot{X}_T - \dot{X}$
$\dot{Y}_{REL} = \dot{Y}_T - \dot{Y}$
$\dot{Z}_{REL} = \dot{Z}_T - \dot{Z}$
RELATIVE VELOCITY
$\dot{X}_{REL}$
$\dot{Y}_{REL}$
$\dot{Z}_{REL}$
$\ddot{X}_{REL} = \ddot{X}_T - \ddot{X}$
$\ddot{Y}_{REL} = \ddot{Y}_T - \ddot{Y}$
$\ddot{Z}_{REL} = \ddot{Z}_T - \ddot{Z}$
RELATIVE ACCELERATION
$\ddot{X}_{REL}$
$\ddot{Y}_{REL}$
$\ddot{Z}_{REL}$
$r = (X_{REL}^2 + Y_{REL}^2 + Z_{REL}^2)^{1/2}$ $\dot{r} = \frac{X_{REL}\dot{X}_{REL} + Y_{REL}\dot{Y}_{REL} + Z_{REL}\dot{Z}_{REL}}{r}$
MISSILE AND TARGET RANGE AND RANGE RATE
r
$\dot{r}$
$\ddot{r} = \frac{\dot{X}_{REL}^2 + \dot{Y}_{REL}^2 + \dot{Z}_{REL}^2}{r} + \frac{X_{REL}\ddot{X}_{REL} + Y_{REL}\ddot{Y}_{REL} + Z_{REL}\ddot{Z}_{REL}}{r} - \frac{\dot{r}^2}{r}$
IF $\dot{r}$ < -600 OUTPUT
MISSILE VELOCITY SLOW FOR GUIDANCE (NO, ABORT)
IF T ≥ 5 AND $\dot{r}$ > 0 ABORT
MISSILE CLOSING POSITIVE
ABORT
$TTG = -\frac{r}{\dot{r}}$
TIME TO GO
TTG
$MISS = r + \dot{r}(TTG) + \frac{\ddot{r}}{2}(TTG)^2$
MISS

Figure 4.5. Missile and target range and velocity computations

Table 4-5. Range and range rate between missile and target subroutines



```
SUBROUTINE MTRVEL      74/74    OPT=1                          FTN 4.2+P343        05/01/75  13.31.11.

                 SUBROUTINE MTRVEL(X,XP,X20,X40,XP40,X70,X90,XP90,T,VM,VM0,VT,VT0   MAR19      66
                1,REL,L2,TTG,RMISS,MSG1)                                            MTRNGVEL    3
                 DIMENSION X(10),XP(10),REL(12)                                     MTRNGVEL    4
                 XP(1)=X(1)                                                         MTRNGVEL    5
                 XP(2)=X(2)                                                         MTRNGVEL    6
                 XP(4)=X(4)                                                         MTRNGVEL    7
                 XP(7)=X(7)                                                         MTRNGVEL    8
                 VM=SQRT(X(2)*X(2)+X(4)*X(4)+XP(4)*XP(4))                           MTRNGVEL    9
                 VM0=SQRT(X20*X20+X40*X40+XP40*XP40)                                MTRNGVEL   10
                 VT=SQRT(X(7)*X(7)+X(9)*X(9)+XP(9)*XP(9))                           MTRNGVEL   11
                 VT0=SQRT(X70*X70+X90*X90+XP90*XP90)                                MTRNGVEL   12
                 REL(1)=X(6)-X(1)                                                   MTRNGVEL   13
                 REL(2)=X(8)-X(3)                                                   MTRNGVEL   14
                 REL(3)=XP(8)-XP(3)                                                 MTRNGVEL   15
                 REL(4)=X(7)-X(2)                                                   MTRNGVEL   16
                 REL(5)=X(9)-X(4)                                                   MTRNGVEL   17
                 REL(6)=XP(9)-XP(4)                                                 MTRNGVEL   18
                 REL(7)=X70-X20                                                     MTRNGVEL   19
                 REL(8)=X90-X40                                                     MTRNGVEL   20
                 REL(9)=XP90-XP40                                                   MTRNGVEL   21
                 REL(10)=SQRT(REL(1)*REL(1)+REL(2)*REL(2)+REL(3)*REL(3))            MTRNGVEL   22
                 AA=REL(1)*REL(4)+REL(2)*REL(5)+REL(3)*REL(6)                       MTRNGVEL   23
                 REL(11)=AA/REL(10)                                                 MTRNGVEL   24
                 A=REL(4)*REL(4)+REL(5)*REL(5)+REL(6)*REL(6)                        MTRNGVEL   25
                 B=REL(1)*REL(7)+REL(2)*REL(8)+REL(3)*REL(9)                        MTRNGVEL   26
                 REL(12)=A/REL(10)+B/REL(10)-REL(11)*REL(11)/REL(10)                MTRNGVEL   27
                 IF(REL(11).GE.-500.) GO TO 6                                       MTRNGVEL   28
                 GO TO 7                                                            MTRNGVEL   29
               6 MSG1=0                                                             MTRNGVEL   30
                 GO TO 2                                                            MTRNGVEL   31
               7 MSG1=MSG1+1                                                        MTRNGVEL   32
                 IF(MSG1.GT.1) GO TO 2                                              MTRNGVEL   33
                 WRITE(6,1)                                                         MTRNGVEL   34
               1 FORMAT(1X,45HMISSILE VELOCITY SLOW FOR GUIDANCE (NO ABORT))        MTRNGVEL   35
               2 IF(T.GE.5..AND.REL(11).GT.0.) GO TO 5                              MTRNGVEL   36
                 GO TO 3                                                            MTRNGVEL   37
               5 WRITE(6,4)                                                         MTRNGVEL   38
               4 FORMAT(1X 26HMISSILE CLOSING POSITIVE)                             MAR19      67
                 WRITE(6,8) REL(1),REL(2),REL(3),REL(4),REL(5),REL(6)               MAR19      68
               8 FORMAT(1X,61HREL(1),REL(2),REL(3),REL(4),REL(5),REL(6),/,6(1X,E12. MAR19      69
                1 5))                                                               MAR19      70
                 WRITE(6,9) X(8),XP(8),XP(9)                                        MAR19      71
               9 FORMAT(1X,5HX(8)=,E12.5,1X,6HXP(8)=,E12.5,1X,6HXP(9)=,E12.5)       MAR19      72
                 WRITE(6,10) X(1),X(2),X(3),X(4),X(5),XP(4),XP(9),XP(3),X(9),X(7)   MAR19      73
              10 FORMAT(1X,64HX(1),X(2),X(3),X(4),X(5),XP(4),XP(9),XP(3),X(9),X(7),/,9(1X MAR19 74
                1,E12.4))                                                           MAR19      75
                 WRITE(6,11) T,REL(11),L2                                           MAR19      76
              11 FORMAT(1X,2HT=,E12.6,1X,8HREL(11)=,E10.3,1X,3HL2=,I2)              MTRNGVEL   44
                 L2=2                                                               MTRNGVEL   45
               3 TTG=-AA/A                                                          MTRNGVEL   46
                 RMISS=REL(10)+REL(11)*TTG+REL(12)*.5*TTG*TTG                       MTRNGVEL   47
                 RETURN                                                             MTRNGVEL   48
                 END
```

Table 4-6. Range and range rate between missile and flare subroutine

```
SUBROUTINE MFLRVEL    74/74   OPT=1                         FTN 4.2+P390      05/01/75  13.31.02.

              SUBROUTINE MFLRVEL(N,XF,XFP,XFD,VF,AF,RELF)                           MAR19       62
              DIMENSION XF(13,23),XFP(13,23),XFD(13,23),RELF(8,23)                  MISSFLRV     3
              DIMENSION VF(23),AF(23)                                               MISSFLRV     4
              DO 1 K=1,N                                                            MISSFLRV     5
              VF(K)=SQRT(XF(7,K)*XF(7,K)+XF(8,K)*XF(9,K)+XFP(9,K)*XFP(9,K))          MISSFLRV     6
              AF(K)=SQRT(XFD(1,K)*XFD(1,K)+XFD(2,K)*XFD(2,K)+XFD(3,K)*XFD(3,K))     MISSFLRV     7
              RELF(1,K)=XF(4,K)-XF(1,K)                                             MISSFLRV     8
              RELF(2,K)=XF(5,K)-XF(2,K)                                             MISSFLRV     9
              RELF(3,K)=XFP(4,K)-XFP(1,K)                                           MISSFLRV    10
              RELF(4,K)=XF(7,K)-XF(2,K)                                             MISSFLRV    11
              RELF(5,K)=XF(9,K)-XF(6,K)                                             MISSFLRV    12
              RELF(6,K)=XFP(9,K)-XFP(6,K)                                           MISSFLRV    13
              RELF(7,K)=SQRT(RELF(1,K)*RELF(1,K)+RELF(2,K)*RELF(2,K)+RELF(3,K)*R    MISSFLRV    14
             +ELF(3,K))                                                             MISSFLRV    15
              RELF(8,K)=(RELF(1,K)*RELF(4,K)+RELF(2,K)*RELF(5,K)+RELF(3,K)*RELF(    MISSFLRV    16
             +6,K))/RELF(7,K)                                                       MISSFLRV    17
            1 CONTINUE                                                              MISSFLRV    18
            2 RETURN                                                                MISSFLRV    19
              END                                                                   MISSFLRV    20
```

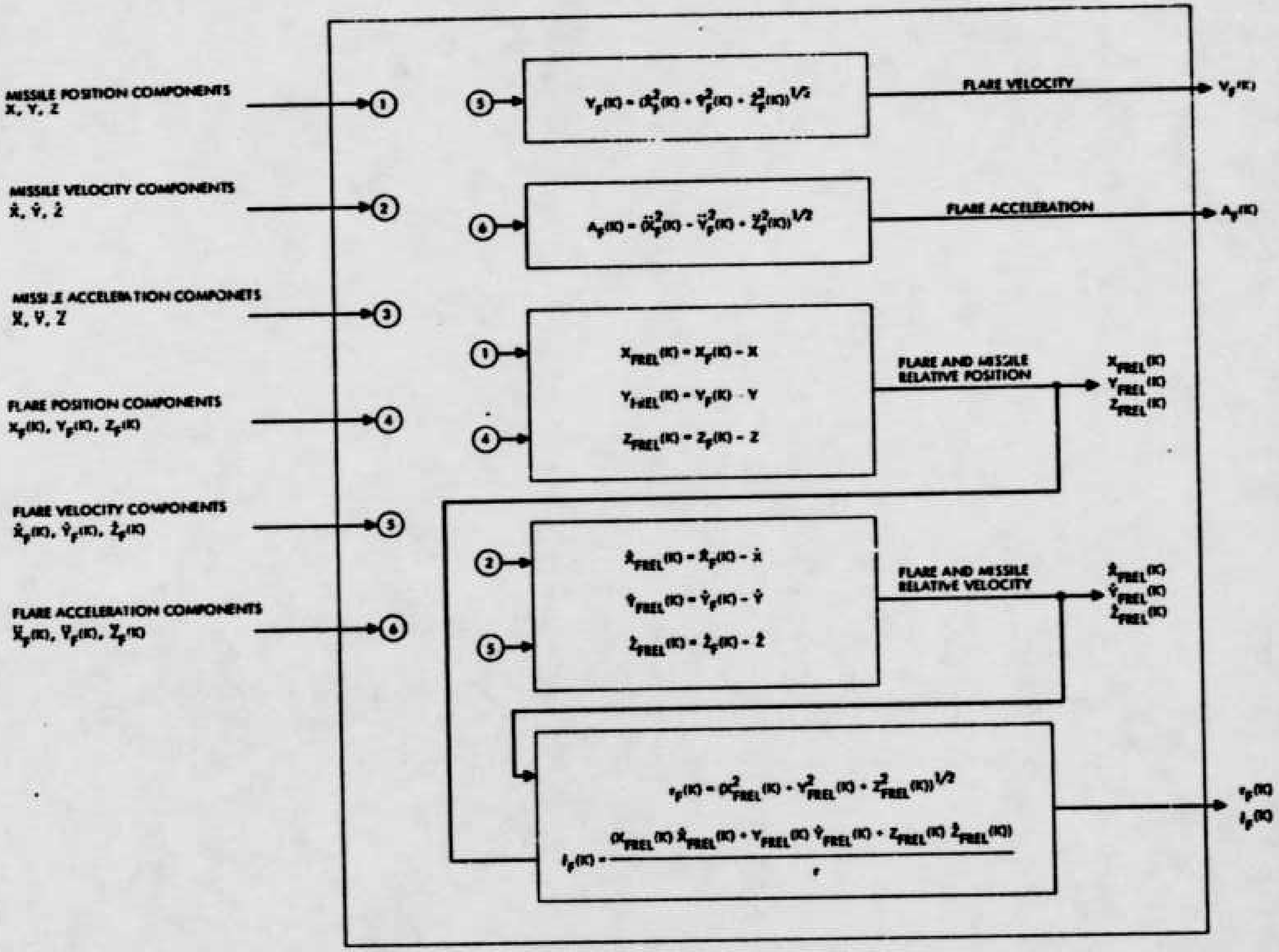

MISSILE POSITION COMPONENTS
X, Y, Z
MISSILE VELOCITY COMPONENTS
$\dot{X}, \dot{Y}, \dot{Z}$
MISSI E ACCELERATION COMPONETS
$\ddot{X}, \ddot{Y}, \ddot{Z}$
FLARE POSITION COMPONENTS
$X_F(K), Y_F(K), Z_F(K)$
FLARE VELOCITY COMPONENTS
$\dot{X}_F(K), \dot{Y}_F(K), \dot{Z}_F(K)$
FLARE ACCELERATION COMPONENTS
$\ddot{X}_F(K), \ddot{Y}_F(K), \ddot{Z}_F(K)$
1
2
3
4
5
6
5
$V_F(K) = (\dot{X}_F^2(K) + \dot{Y}_F^2(K) + \dot{Z}_F^2(K))^{1/2}$
FLARE VELOCITY
$V_F(K)$
6
$A_F(K) = (\ddot{X}_F^2(K) + \ddot{Y}_F^2(K) + \ddot{Z}_F^2(K))^{1/2}$
FLARE ACCELERATION
$A_F(K)$
1
4
$X_{FREL}(K) = X_F(K) - X$
$Y_{FREL}(K) = Y_F(K) - Y$
$Z_{FREL}(K) = Z_F(K) - Z$
FLARE AND MISSILE RELATIVE POSITION
$X_{FREL}(K)$
$Y_{FREL}(K)$
$Z_{FREL}(K)$
2
5
$\dot{X}_{FREL}(K) = \dot{X}_F(K) - \dot{X}$
$\dot{Y}_{FREL}(K) = \dot{Y}_F(K) - \dot{Y}$
$\dot{Z}_{FREL}(K) = \dot{Z}_F(K) - \dot{Z}$
FLARE AND MISSILE RELATIVE VELOCITY
$\dot{X}_{FREL}(K)$
$\dot{Y}_{FREL}(K)$
$\dot{Z}_{FREL}(K)$
$r_F(K) = (X_{FREL}^2(K) + Y_{FREL}^2(K) + Z_{FREL}^2(K))^{1/2}$
$\dot{r}_F(K) = \frac{(X_{FREL}(K)\,\dot{X}_{FREL}(K) + Y_{FREL}(K)\,\dot{Y}_{FREL}(K) + Z_{FREL}(K)\,\dot{Z}_{FREL}(K))}{r}$
$r_F(K)$
$\dot{r}_F(K)$

Figure 4-6. Missile and flare range and velocity computations

5. TARGET AND FLARE IRRADIANCE COMPUTATIONS

This portion of the program determines the irradiance from the target and flare at the missile dome. Section 5.1 describes the target irradiance computations, and Section 5.2 describes the flare irradiance computations.

5.1 TARGET IRRADIANCE COMPUTATIONS

In determining the irradiance at the missile from the target there are several major factors which must be determined as indicated in Figure 5-1.

First, the aspect angle at which the missile views the aircraft must be determined. This is found from the dot product relationship.

$$V_T \cdot r = V_T\, r \cos \theta$$

or

$$\dot{X}_T\, r_X + \dot{Y}_T\, r_Y + \dot{Z}_T r_Z = V_T\, r \cos \theta$$

where,

V_T = target velocity

r = missile/target range

$\dot{X}_T, \dot{Y}_T, \dot{Z}_T$ = X, Y, Z components of target velocity

r_X, r_Y, r_Z = X, Y, Z components of missile/target range

θ = aspect angle.

The target intensity data is stored in the program as a function of polar angle. Once the aspect viewing angle has been determined the value of the target intensity is found by means of a table look up on this data.

Data on atmospheric attenuation is stored in the program as a function of range and black body temperature. Based on the aircraft tailpipe temperature and the missile/target range, the atmospheric attenuation is found by means of a table look up.

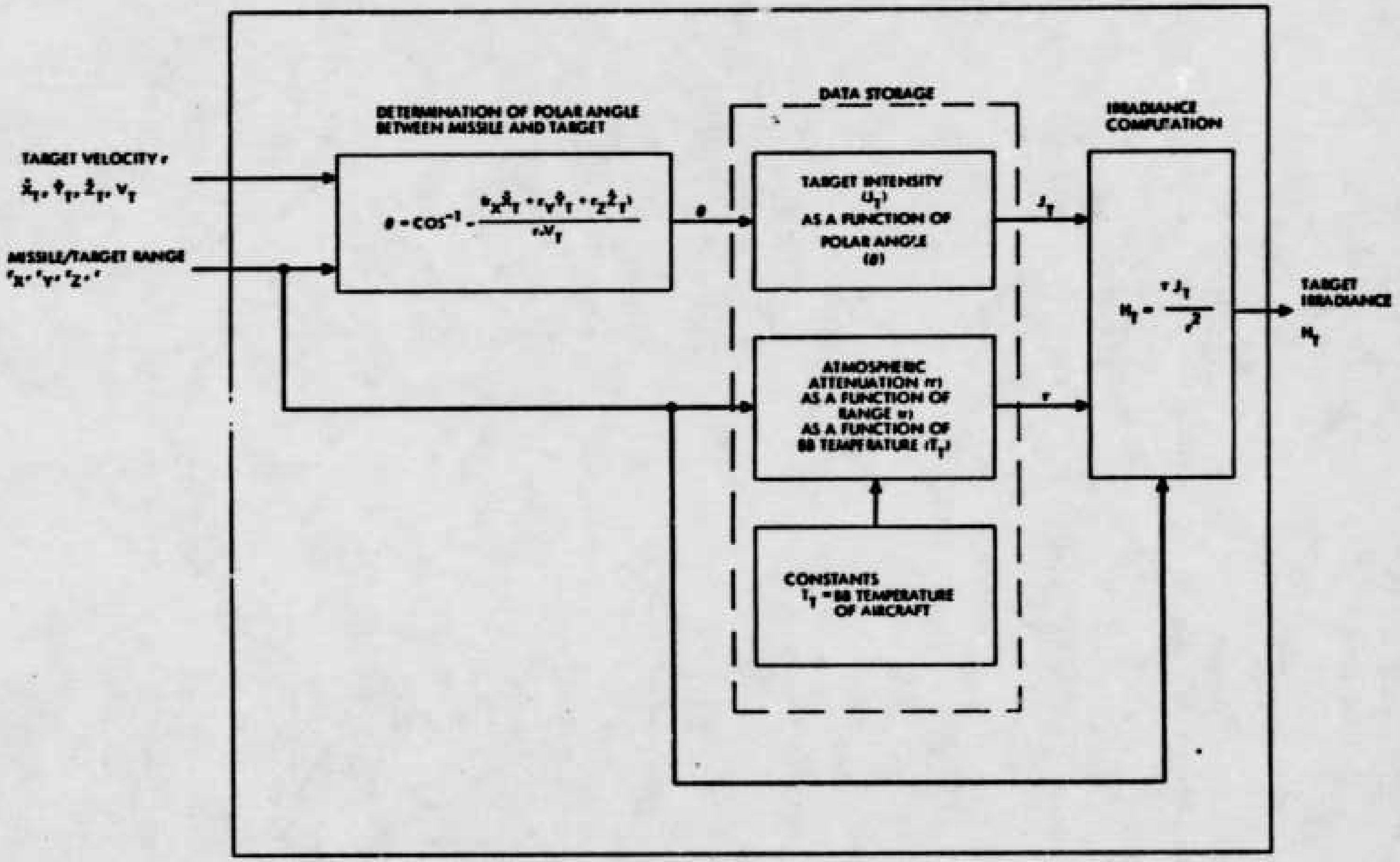
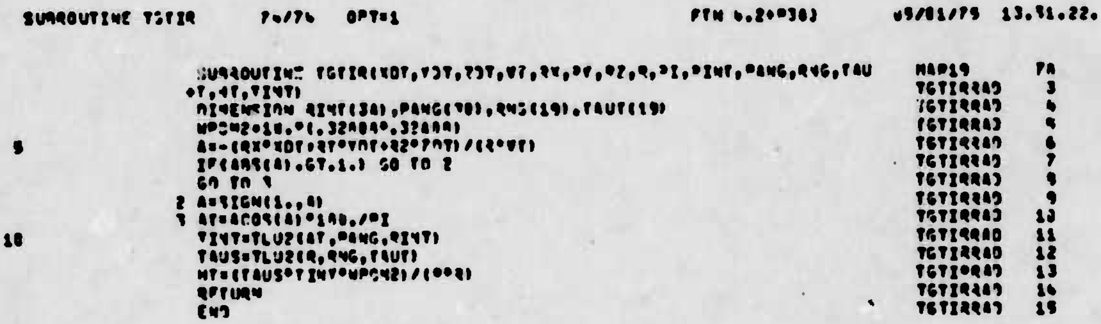

TARGET VELOCITY r
$\dot{x}_T, \dot{y}_T, \dot{z}_T, V_T$
MISSILE/TARGET RANGE
r_X, r_Y, r_Z, r
DETERMINATION OF POLAR ANGLE BETWEEN MISSILE AND TARGET
$\theta = \cos^{-1} \frac{(r_X \dot{x}_T + r_Y \dot{y}_T + r_Z \dot{z}_T)}{r V_T}$
θ
DATA STORAGE
TARGET INTENSITY (J_T) AS A FUNCTION OF POLAR ANGLE (θ)
ATMOSPHERIC ATTENUATION (τ) AS A FUNCTION OF RANGE (r) AS A FUNCTION OF BB TEMPERATURE (T_T)
CONSTANTS T_T = BB TEMPERATURE OF AIRCRAFT
J_T
τ
IRRADIANCE COMPUTATION
$H_T = \frac{\tau J_T}{r^2}$
TARGET IRRADIANCE
H_T

Figure 5-1. Target irradiance computation

The irradiance from the target is then computed, as indicated in Figure 5-1, based on the target intensity, atmospheric attenuation and missile/target range. A listing of this subroutine is contained in Table 5-1. Note: The EPICS program consists of ASDIR II in conjunction with the SPKINT subroutine and M/T/CM. As we have just seen, M/T/CM contains an atmospheric transmission file. Thus, when using ASDIR II (or any other program which generates spectral radiant intensity) it is important to use a true (unattenuated) spectral radiant intensity.

If it is desired to use a different atmospheric transmission model, this latter model must be used (in conjunction with target temperature, altitude, range and optical waveband) to generate a new atmospheric file in the M/T/CM program.

Table 5-1. Target irradiance subroutine

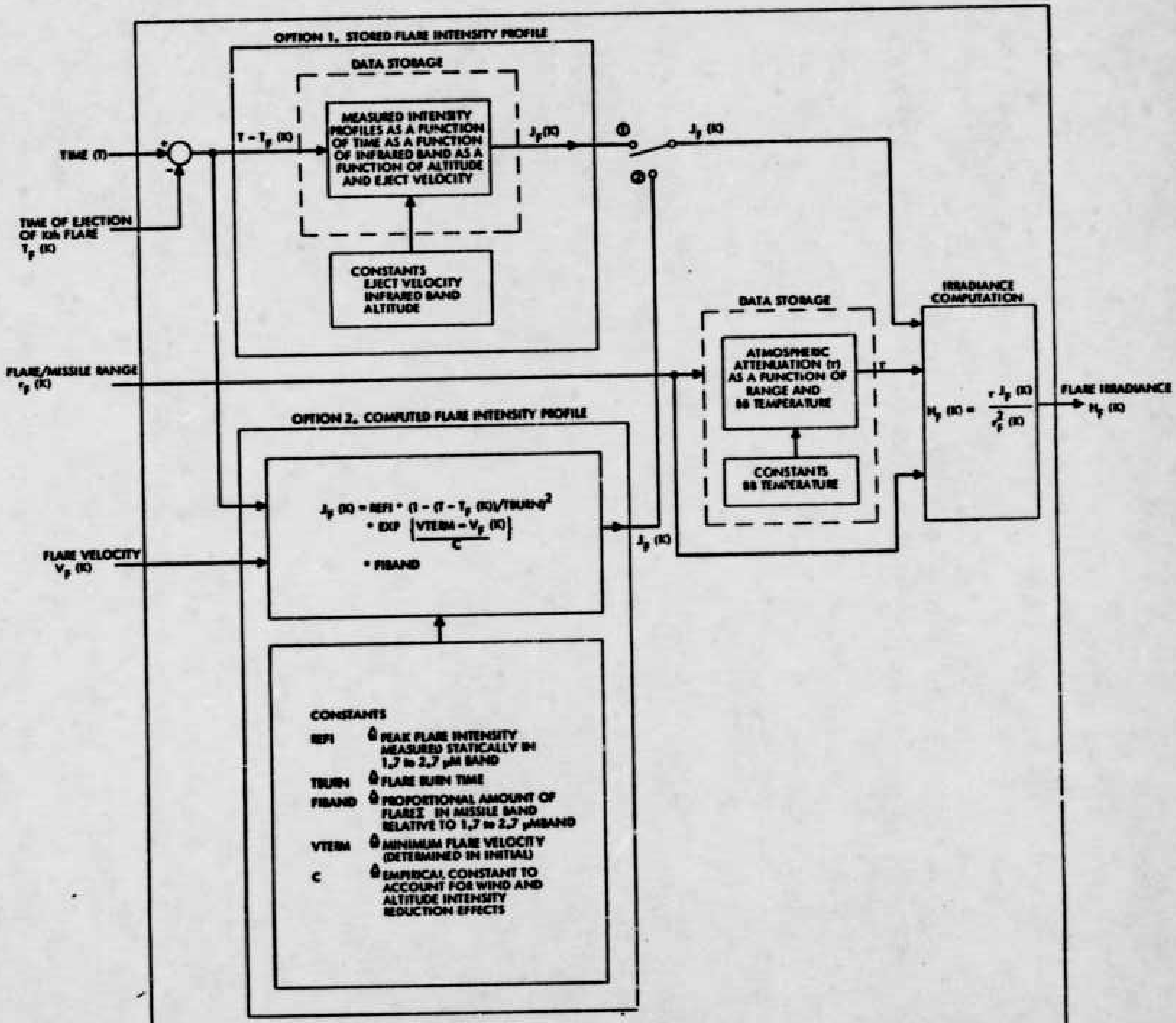


```
SUBROUTINE TGTIR      74/74   OPT=1                         FTN 4.2+P380        09/01/75  13.31.22.

                SUBROUTINE TGTIR(XDT,YDT,ZDT,VT,RX,RY,RZ,R,PI,RINT,PANG,RNG,TAU    MAP19       7A
               +T,HT,TINT)                                                          TGTIRRAD     3
                DIMENSION RINT(30),PANG(30),RNG(19),TAUT(19)                        TGTIRRAD     4
                WPCM2=10.**(.32808*.32808)                                          TGTIRRAD     5
                A=-(RX*XDT+RY*YDT+RZ*ZDT)/(R*VT)                                    TGTIRRAD     6
                IF(ABS(A).GT.1.) GO TO 2                                            TGTIRRAD     7
                GO TO 3                                                             TGTIRRAD     8
              2 A=SIGN(1.,A)                                                        TGTIRRAD     9
              3 AT=ACOS(A)*180./PI                                                  TGTIRRAD    10
                TINT=TLU2(AT,PANG,RINT)                                             TGTIRRAD    11
                TAUS=TLU2(R,RNG,TAUT)                                               TGTIRRAD    12
                HT=(TAUS*TINT*WPCM2)/(R*R)                                          TGTIRRAD    13
                RETURN                                                              TGTIRRAD    14
                END                                                                 TGTIRRAD    15
```

5.2 FLARE IRRADIANCE COMPUTATIONS

The program allows for two options in determining the flare intensity profile as indicated in Figure 5-2. Option 1 uses a table look up procedure for determing the flare intensity as a function of time. This procedure is generally used when dynamic, in flight intensity profiles are available for altitude and windstream conditions at or near those being considered. When no dynamic, in flight data exists, option 2 can be used to generate an intensitv profile which accounts for altitude and windstream degradation factors. Basically this model consists of four factors. First, a peak flare intensity value (REFI) measured statically and referenced to the 1.7-2.7μ band is


OPTION 1. STORED FLARE INTENSITY PROFILE
DATA STORAGE
MEASURED INTENSITY PROFILES AS A FUNCTION OF TIME AS A FUNCTION OF INFRARED BAND AS A FUNCTION OF ALTITUDE AND EJECT VELOCITY
CONSTANTS EJECT VELOCITY INFRARED BAND ALTITUDE
TIME (T)
TIME OF EJECTION OF Kth FLARE T_F (K)
+
-
$T - T_F$ (K)
J_F (K)
①
②
J_F (K)
FLARE/MISSILE RANGE r_F (K)
DATA STORAGE
ATMOSPHERIC ATTENUATION (τ) AS A FUNCTION OF RANGE AND BB TEMPERATURE
CONSTANTS BB TEMPERATURE
τ
IRRADIANCE COMPUTATION
$H_F(K) = \frac{\tau \cdot J_F(K)}{r_F^2(K)}$
FLARE IRRADIANCE H_F (K)
OPTION 2. COMPUTED FLARE INTENSITY PROFILE
$J_F(K) = REFI * (1 - (T - T_F(K))/TBURN)^2 * EXP\left[\frac{VTERM - V_F(K)}{C}\right] * FIBAND$
J_F (K)
FLARE VELOCITY V_F (K)
CONSTANTS
REFI ≜ PEAK FLARE INTENSITY MEASURED STATICALLY IN 1.7 to 2.7 μM BAND
TBURN ≜ FLARE BURN TIME
FIBAND ≜ PROPORTIONAL AMOUNT OF FLAREΣ IN MISSILE BAND RELATIVE TO 1.7 to 2.7 μMBAND
VTERM ≜ MINIMUM FLARE VELOCITY (DETERMINED IN INITIAL)
C ≜ EMPIRICAL CONSTANT TO ACCOUNT FOR WIND AND ALTITUDE INTENSITY REDUCTION EFFECTS

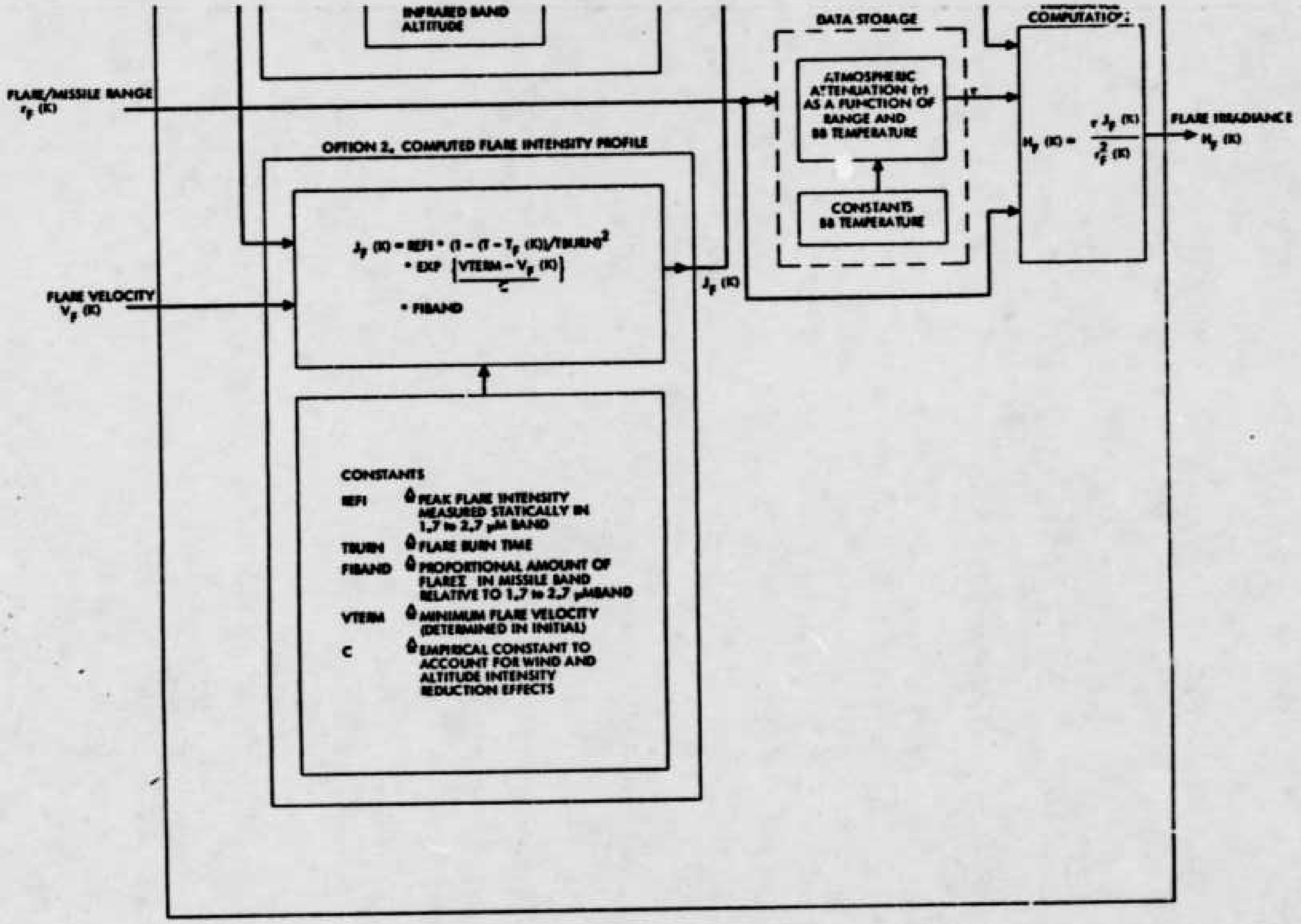

INFRARED BAND
ALTITUDE
FLARE/MISSILE RANGE
r_F (K)
OPTION 2, COMPUTED FLARE INTENSITY PROFILE
J_F (K) = REFI * (1 − (T − T_F (K))/TBURN)^2
* EXP $\left[\frac{\text{VTERM} - V_F(K)}{C}\right]$
* FIBAND
FLARE VELOCITY
V_F (K)
J_F (K)
CONSTANTS
REFI ≙ PEAK FLARE INTENSITY MEASURED STATICALLY IN 1.7 to 2.7 μM BAND
TBURN ≙ FLARE BURN TIME
FIBAND ≙ PROPORTIONAL AMOUNT OF FLAREΣ IN MISSILE BAND RELATIVE TO 1.7 to 2.7 μMBAND
VTERM ≙ MINIMUM FLARE VELOCITY (DETERMINED IN INITIAL)
C ≙ EMPIRICAL CONSTANT TO ACCOUNT FOR WIND AND ALTITUDE INTENSITY REDUCTION EFFECTS
DATA STORAGE
ATMOSPHERIC ATTENUATION (τ) AS A FUNCTION OF RANGE AND BB TEMPERATURE
CONSTANTS BB TEMPERATURE
τ
COMPUTATIO
H_F (K) = $\frac{\tau J_F(K)}{r_F^2(K)}$
FLARE IRRADIANCE
H_F (K)

Figure 5-2. Flare irradiance computations

required. Second, the variation in the flare is burning surface area as a function of time is required. The expression shown is for a cylindrical type whose linear burn rate is assumed to be constant. (See reference 1.) Next, the factor

$$\exp\left\{\frac{\text{V term} - V_F\,(K)}{C}\right\} \text{ accounts for}$$

altitude and windstream degradation. This is an empirical expression found to curve fit measured, dynamic flare data quite well. The term V term represents the minimum flare velocity and is determined from trajectory parameters in the initialization portion of the program. (See also Fifth Quarterly Report, IRCM Simulation Study). Finally, the term FIBAND is used to proportion out the flare energy in the missile band being considered relative to the reference band (1.7-2.7μ).

Once the flare intensity has been determined, the atmospheric attenuation is found by means of a table look up, and the irradiance value is computed. A listing of this subroutine is contained in Table 5-2.

Table 5-2. Flare irradiance subroutine

```
SUBROUTINE FLRIR       74/74   OPT=1                    FTN 4.2+P391        03/01/79  13.31.07.

              SUBROUTINE FLRIR(T,TF,RELF,N,VF,JF,HF,IOPT,TIN,JIN,FIBAND,IBNDM   MAR19      64
             +,FSF,REFI,TBURN,VTERM,RNG,TAUF)                                   FLRIRRAD    3
              REAL JF,JIN                                                       FLRIRRAD    4
              DIMENSION FIBAND(9),VTERM(20),FSF(20),RNG(19),TAUF(19)            FLRIRRAD    5
              DIMENSION TF(20),RELF(9,20),VF(20),JF(20),HF(20),TIN(180),JIN(180) FLRIRRAD   6
              HPCM2=1./(.3048*.3048)                                            FLRIRRAD    7
              DO 1 K=1,N                                                        FLRIRRAD    8
              TD=T-TF(K)                                                        FLRIRRAD    9
              IF(TD.LT.(TBURN-.1)) GO TO 8                                      FLRIRRAD   10
              JF(K)=0.                                                          FLRIRRAD   11
              GO TO 6                                                           FLRIRRAD   12
            8 A=1.-TD/TBURN                                                     FLRIRRAD   13
              GO TO (3,4), IOPT                                                 FLRIRRAD   14
            3 JF(K)=TLU2(TD,TIN,JIN)*FIBAND(IBNDM)*FSF(K)                       FLRIRRAD   15
              GO TO 6                                                           FLRIRRAD   16
            4 IF((VTERM(K)-VF(K)).GE.0.) GO TO 7                                FLRIRRAD   17
              JF(K)=REFI*A*A*EXP((VTERM(K)-VF(K))/35.)*FIBAND(IBNDM)/1333.*FSF(K FLRIRRAD  18
             +)                                                                 FLRIRRAD   19
              GO TO 6                                                           FLRIRRAD   20
            7 JF(K)=REFI*A*A*FIBAND(IBNDM)/1333.*FSF(K)                         FLRIRRAD   21
            6 TAU=TLU2(RELF(7,K),RNG,TAUF)                                      FLRIRRAD   22
              HF(K)=TAU*JF(K)*HPCM2/(RELF(7,K)*RELF(7,K))                       FLRIRRAD   23
            1 CONTINUE                                                          FLRIRRAD   24
            2 RETURN                                                            FLRIRRAD   25
              END                                                               FLRIRRAD   26
```

6. . AIMPOINT DETERMINATION

The primary functions of this portion of the program are to

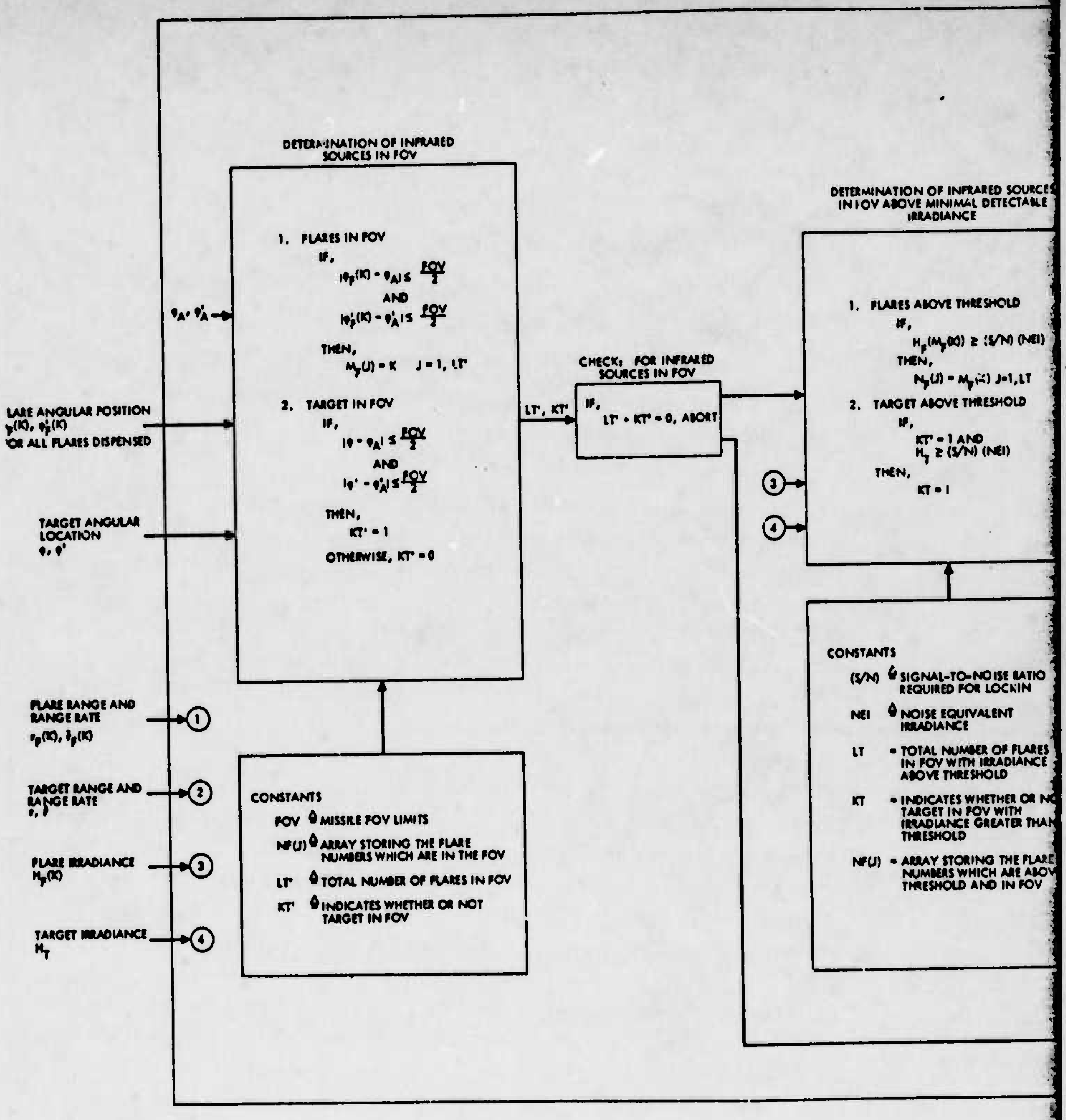
1. Determine which infrared sources are within the missile FOV.
2. Determine which of these sources within the missile FOV have irradiance levels above the minimum detectable.
3. Determine the missile aimpoint, on the basis of the missile's signal processing and source irradiance levels -- within FOV and above minimum detectable.

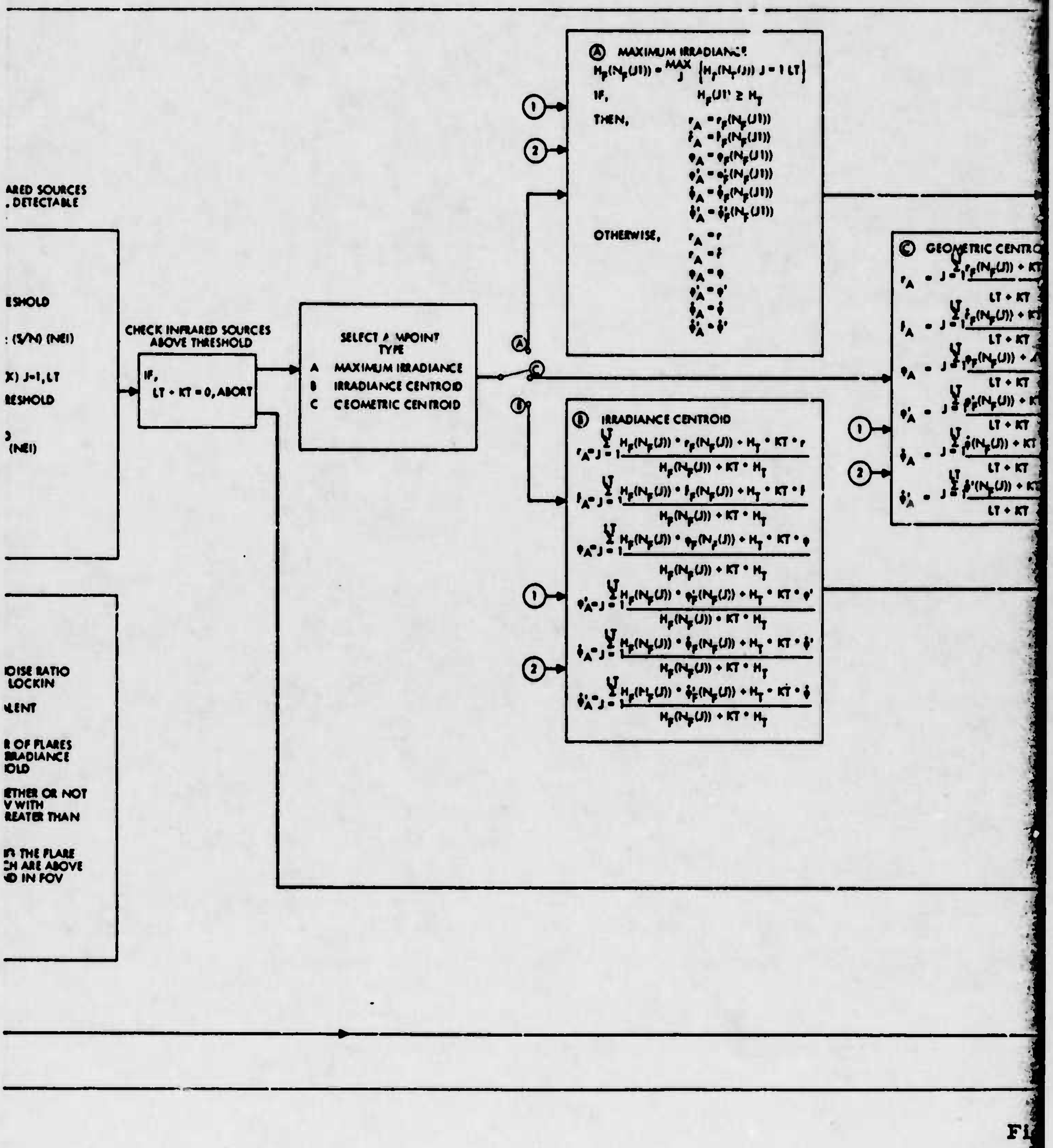
Figure 6-1 describes the computational procedure for determining the aimpoint in block diagram form. A further detailed description of these computations is contained in the following paragraphs. A listing of this subroutine is contained in Table 6-1.

Table 6-2 shows the equations used to check which ignited flares are within the FOV of the missile and they are stored in an array $N_F(J)$ for further aimpoint processing. Similarity, the target is checked to see if it is within the FOV and the information on whether it is or not is stored in the variable KT'.

The total number of flares in the FOV is indicated by the variable LT'. The sum of the variables (LT' + KT') indicates the total number of IR sources in the FOV. If there are none, then the program will go into an abort mode due to the fact that there are no infrared sources in the missile FOV.

If there is at least one infrared source in the FOV, the program determine which IR sources have irradiance levels above the minimum detectable by the missile. The flares which meet this criteria are stored in an array $N_F(J)$ for further aimpoint processing with their total number in the array being indicated by the variable LT. Similarily, the target is checked to see if it is above threshold level and the information on whether it is or not is stored in the variable KT. If the sum of these variable (LT + KT) equals zero, then the program will abort due to the fact that there are no IR sources within the missile FOV above threshold value. If there is at one source which meet. this criteria the program will then determine the aimpoint.


DETERMINATION OF INFRARED SOURCES IN FOV
1. FLARES IN FOV
IF,
$|\theta_F(K) - \theta_A| \le \frac{FOV}{2}$
AND
$|\theta'_F(K) - \theta'_A| \le \frac{FOV}{2}$
THEN,
$M_F(J) = K \quad J = 1, LT'$
2. TARGET IN FOV
IF,
$|\theta - \theta_A| \le \frac{FOV}{2}$
AND
$|\theta' - \theta'_A| \le \frac{FOV}{2}$
THEN,
$KT' = 1$
OTHERWISE, $KT' = 0$
θ_A, θ'_A
LARE ANGULAR POSITION
$\theta_F(K), \theta'_F(K)$
OR ALL FLARES DISPENSED
TARGET ANGULAR LOCATION
θ, θ'
FLARE RANGE AND RANGE RATE
$r_F(K), \dot{r}_F(K)$
1
TARGET RANGE AND RANGE RATE
$r, \dot{r}$
2
FLARE IRRADIANCE
$H_F(K)$
3
TARGET IRRADIANCE
H_T
4
CONSTANTS
FOV $\triangleq$ MISSILE FOV LIMITS
NF(J) $\triangleq$ ARRAY STORING THE FLARE NUMBERS WHICH ARE IN THE FOV
LT' $\triangleq$ TOTAL NUMBER OF FLARES IN FOV
KT' $\triangleq$ INDICATES WHETHER OR NOT TARGET IN FOV
LT', KT'
CHECK: FOR INFRARED SOURCES IN FOV
IF,
$LT' + KT' = 0$, ABORT
DETERMINATION OF INFRARED SOURCES IN FOV ABOVE MINIMAL DETECTABLE IRRADIANCE
1. FLARES ABOVE THRESHOLD
IF,
$H_F(M_F(K)) \ge (S/N)\,(NEI)$
THEN,
$N_F(J) = M_F(K) \quad J=1, LT$
2. TARGET ABOVE THRESHOLD
IF,
$KT' = 1$ AND
$H_T \ge (S/N)\,(NEI)$
THEN,
$KT = 1$
3
4
CONSTANTS
(S/N) $\triangleq$ SIGNAL-TO-NOISE RATIO REQUIRED FOR LOCKIN
NEI $\triangleq$ NOISE EQUIVALENT IRRADIANCE
LT = TOTAL NUMBER OF FLARES IN FOV WITH IRRADIANCE ABOVE THRESHOLD
KT = INDICATES WHETHER OR NO TARGET IN FOV WITH IRRADIANCE GREATER THAN THRESHOLD
NF(J) = ARRAY STORING THE FLARE NUMBERS WHICH ARE ABOV THRESHOLD AND IN FOV


ARED SOURCES
, DETECTABLE
ESHOLD
: (S/N) (NEI)
X) J=1, LT
RESHOLD
(NEI)
IOISE RATIO
LOCKIN
ALENT
R OF FLARES
IRRADIANCE
IOLD
ETHER OR NOT
V WITH
REATER THAN
IS THE FLARE
CH ARE ABOVE
ND IN FOV
CHECK INFRARED SOURCES ABOVE THRESHOLD
IF, LT + KT = 0, ABORT
SELECT AIMPOINT TYPE
A MAXIMUM IRRADIANCE
B IRRADIANCE CENTROID
C GEOMETRIC CENTROID
A
B
C
1
2
Ⓐ MAXIMUM IRRADIANCE
$H_F(N_F(J1)) = \max_J \{H_F(N_F(J)) \; J = 1, LT\}$
IF, $H_F(J1) \geq H_T$
THEN, $r_A = r_F(N_F(J1))$
$\dot{r}_A = \dot{r}_F(N_F(J1))$
$\theta_A = \theta_F(N_F(J1))$
$\theta'_A = \theta'_F(N_F(J1))$
$\dot{\theta}_A = \dot{\theta}_F(N_F(J1))$
$\dot{\theta}'_A = \dot{\theta}'_F(N_F(J1))$
OTHERWISE, $r_A = r$
$r_A = \dot{r}$
$\theta_A = \theta$
$\theta'_A = \theta'$
$\dot{\theta}_A = \dot{\theta}$
$\dot{\theta}'_A = \dot{\theta}'$
Ⓑ IRRADIANCE CENTROID
$r_A = \sum_{J=1}^{LT} \frac{H_F(N_F(J)) \cdot r_F(N_F(J)) + H_T \cdot KT \cdot r}{H_F(N_F(J)) + KT \cdot H_T}$
$\dot{r}_A = \sum_{J=1}^{LT} \frac{H_F(N_F(J)) \cdot \dot{r}_F(N_F(J)) + H_T \cdot KT \cdot \dot{r}}{H_F(N_F(J)) + KT \cdot H_T}$
$\theta_A = \sum_{J=1}^{LT} \frac{H_F(N_F(J)) \cdot \theta_F(N_F(J)) + H_T \cdot KT \cdot \theta}{H_F(N_F(J)) + KT \cdot H_T}$
$\theta'_A = \sum_{J=1}^{LT} \frac{H_F(N_F(J)) \cdot \theta'_F(N_F(J)) + H_T \cdot KT \cdot \theta'}{H_F(N_F(J)) + KT \cdot H_T}$
$\dot{\theta}_A = \sum_{J=1}^{LT} \frac{H_F(N_F(J)) \cdot \dot{\theta}_F(N_F(J)) + H_T \cdot KT \cdot \dot{\theta}'}{H_F(N_F(J)) + KT \cdot H_T}$
$\dot{\theta}'_A = \sum_{J=1}^{LT} \frac{H_F(N_F(J)) \cdot \dot{\theta}'_F(N_F(J)) + H_T \cdot KT \cdot \dot{\theta}}{H_F(N_F(J)) + KT \cdot H_T}$
Ⓒ GEOMETRIC CENTRO
$r_A = \sum_{J=1}^{LT} \frac{r_F(N_F(J)) + KT}{LT + KT}$
$\dot{r}_A = \sum_{J=1}^{LT} \frac{\dot{r}_F(N_F(J)) + KT}{LT + KT}$
$\theta_A = \sum_{J=1}^{LT} \frac{\theta_F(N_F(J)) + K}{LT + KT}$
$\theta'_A = \sum_{J=1}^{LT} \frac{\theta'_F(N_F(J)) + K}{LT + KT}$
$\dot{\theta}_A = \sum_{J=1}^{LT} \frac{\dot{\theta}(N_F(J)) + KT}{LT + KT}$
$\dot{\theta}'_A = \sum_{J=1}^{LT} \frac{\dot{\theta}'(N_F(J)) + KT}{LT + KT}$

Fi

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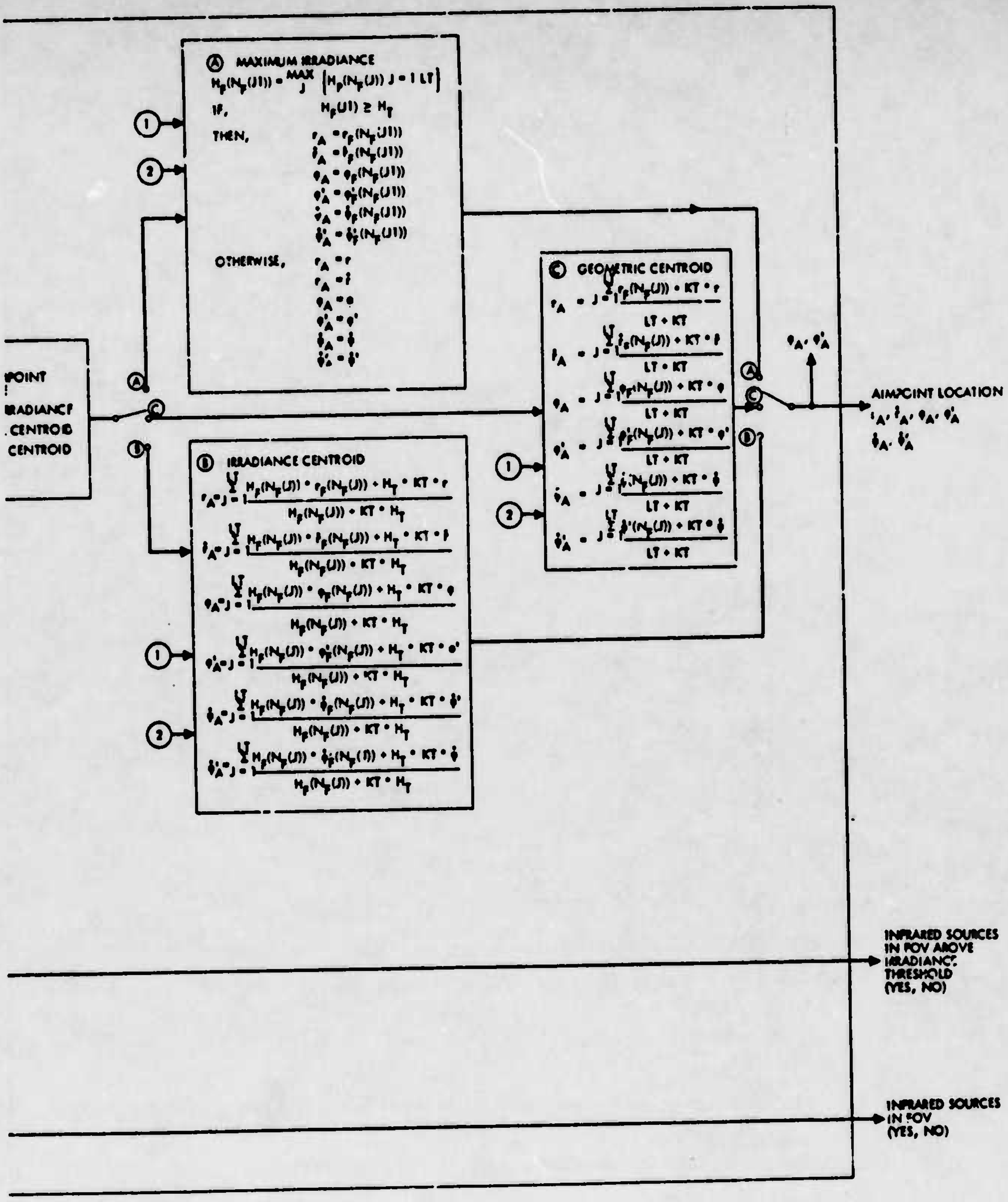
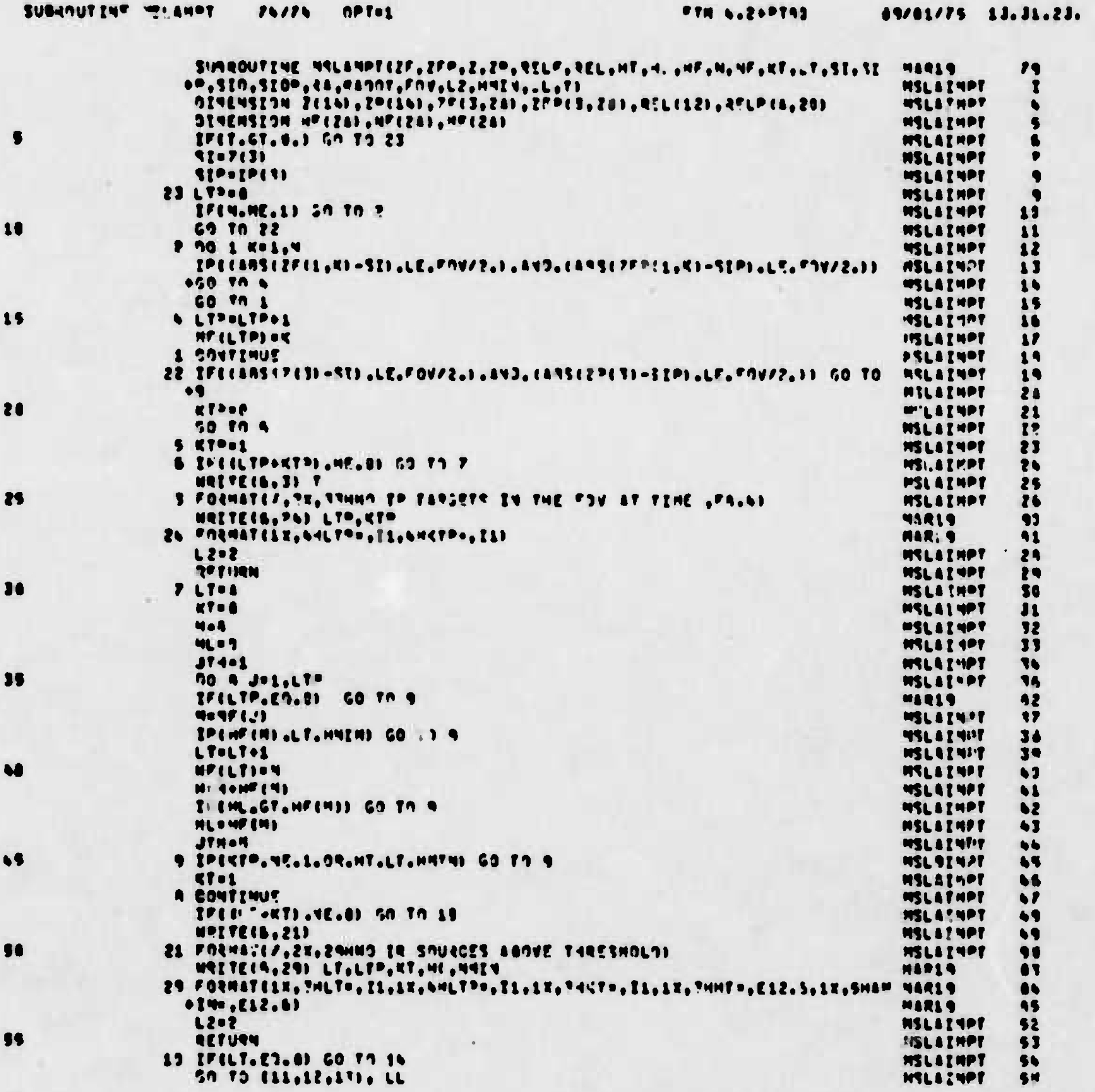


Figure 6-1. Missile aimpoint determination

Table 6-1. Aimpoint determination subroutine

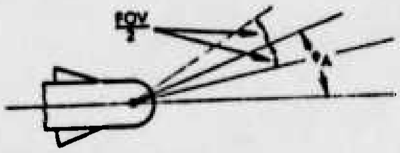


```
SUBROUTINE MSLAMPT     74/74    OPT=1                      FTN 4.2+P393        09/01/75  13.31.23.

      SUBROUTINE MSLAMPT(ZF,ZFP,Z,ZP,RELP,REL,HT,H..,MF,N,NF,KT,LT,SI,SI  MAR19      79
     *P,SIO,SIOP,AA,RADOT,FOV,L2,MMIN,LL,T)                                MSLAIMPT    3
      DIMENSION Z(16),ZP(16),ZF(3,20),ZFP(3,20),REL(12),RELP(4,20)         MSLAIMPT    4
      DIMENSION MF(20),NF(20),HF(20)                                       MSLAIMPT    5
      IF(T.GT.0.) GO TO 23                                                 MSLAIMPT    6
      SI=Z(3)                                                              MSLAIMPT    7
      SIP=ZP(3)                                                            MSLAIMPT    8
   23 LTP=0                                                                MSLAIMPT    9
      IF(N.NE.1) GO TO 2                                                   MSLAIMPT   10
      GO TO 22                                                             MSLAIMPT   11
    2 DO 1 K=1,N                                                           MSLAIMPT   12
      IF((ABS(ZF(1,K)-SI).LE.FOV/2.).AND.(ABS(ZFP(1,K)-SIP).LE.FOV/2.))    MSLAIMPT   13
     *GO TO 4                                                              MSLAIMPT   14
      GO TO 1                                                              MSLAIMPT   15
    4 LTP=LTP+1                                                            MSLAIMPT   16
      MF(LTP)=K                                                            MSLAIMPT   17
    1 CONTINUE                                                             MSLAIMPT   18
   22 IF((ABS(Z(3)-SI).LE.FOV/2.).AND.(ABS(ZP(3)-SIP).LE.FOV/2.)) GO TO   MSLAIMPT   19
     *5                                                                    MSLAIMPT   20
      KTP=0                                                                MSLAIMPT   21
      GO TO 6                                                              MSLAIMPT   22
    5 KTP=1                                                                MSLAIMPT   23
    6 IF((LTP+KTP).NE.0) GO TO 7                                           MSLAIMPT   24
      WRITE(6,3) T                                                         MSLAIMPT   25
    3 FORMAT(/,2X,33HNO IP TARGETS IN THE FOV AT TIME ,F9.4)               MSLAIMPT   26
      WRITE(6,26) LTP,KTP                                                  MAR19      90
   26 FORMAT(1X,4HLTP=,I1,4HKTP=,I1)                                       MAR19      91
      L2=2                                                                 MSLAIMPT   28
      RETURN                                                               MSLAIMPT   29
    7 LT=0                                                                 MSLAIMPT   30
      KT=0                                                                 MSLAIMPT   31
      M=0                                                                  MSLAIMPT   32
      ML=0                                                                 MSLAIMPT   33
      JTM=1                                                                MSLAIMPT   34
      DO 8 J=1,LTP                                                         MSLAIMPT   35
      IF(LTP.EQ.0)  GO TO 9                                                MAR19      92
      M=MF(J)                                                              MSLAIMPT   37
      IF(HF(M).LT.MMIN) GO TO 8                                            MSLAIMPT   38
      LT=LT+1                                                              MSLAIMPT   39
      NF(LT)=M                                                             MSLAIMPT   40
      HL4=HF(M)                                                            MSLAIMPT   41
      IF(HL.GT.HF(M)) GO TO 8                                              MSLAIMPT   42
      HL=HF(M)                                                             MSLAIMPT   43
      JTM=M                                                                MSLAIMPT   44
    9 IF(KTP.NE.1.OR.HT.LT.MMIN) GO TO 8                                   MSLAIMPT   45
      KT=1                                                                 MSLAIMPT   46
    8 CONTINUE                                                             MSLAIMPT   47
      IF((LT+KT).NE.0) GO TO 10                                            MSLAIMPT   48
      WRITE(6,21)                                                          MSLAIMPT   49
   21 FORMAT(/,2X,29HNO IR SOURCES ABOVE THRESHOLD)                        MSLAIMPT   50
      WRITE(6,29) LT,LTP,KT,HL,MMIN                                        MAR19      87
   29 FORMAT(1X,3HLT=,I1,1X,4HLTP=,I1,1X,3HKT=,I1,1X,3HHT=,E12.5,1X,5HMM  MAR19      88
     *IN=,E12.6)                                                           MAR19      89
      L2=2                                                                 MSLAIMPT   52
      RETURN                                                               MSLAIMPT   53
   10 IF(LT.EQ.0) GO TO 14                                                 MSLAIMPT   54
      GO TO (11,12,13), LL                                                 MSLAIMPT   55
```

(Table 6-1, concluded)

```
SUBROUTINE MSLAIMPT     74/74   OPT=1                         FTN 4.2+P380        05/01/79  13.31.23.

               11 A=1                                                              MSLAIMPT    56
                  B=FLOAT(KT)                                                      MSLAIMPT    57
                  C=FLOAT(LT-KT)                                                   MSLAIMPT    58
                  GO TO 19                                                         MSLAIMPT    59
               12 B=FLOAT(KT)*HT                                                   MSLAIMPT    60
                  C=FLOAT(KT)*HT+H                                                 MSLAIMPT    61
               16 RA=0                                                             MSLAIMPT    62
                  RADOT=0.                                                         MSLAIMPT    63
                  SI=0.                                                            MSLAIMPT    64
                  SIP=0.                                                           MSLAIMPT    65
                  SIQ=0.                                                           MSLAIMPT    66
                  SIQP=0.                                                          MSLAIMPT    67
                  DO 15 J=1,LT                                                     MSLAIMPT    68
                  J1=MF(J)                                                         MSLAIMPT    69
                  GO TO (17,18), LL                                                MSLAIMPT    70
               18 A=AF(J1)                                                         MSLAIMPT    71
               17 RA=RA+RELF(7,J1)*A                                               MSLAIMPT    72
                  RADOT=RADOT+RELF(9,J1)*A                                         MSLAIMPT    73
                  SI=SI+ZF(1,J1)*A                                                 MSLAIMPT    74
                  SIP=SIP+ZFP(1,J1)*A                                              MSLAIMPT    75
                  SIQ=SIQ+ZF(2,J1)*A                                               MSLAIMPT    76
               15 SIQP=SIQP+ZFP(2,J1)*A                                            MSLAIMPT    77
                  RA=(RA+B*REL(10))/C                                              MSLAIMPT    78
                  RADOT=(RADOT+B*REL(11))/C                                        MSLAIMPT    79
                  SI=(SI+B*Z(3))/C                                                 MSLAIMPT    80
                  SIP=(SIP+B*ZP(3))/C                                              MSLAIMPT    81
                  SIQ=(SIQ+B*Z(4))/C                                               MSLAIMPT    82
                  SIQP=(SIQP+B*ZP(4))/C                                            MSLAIMPT    83
                  ML=M                                                             MSLAIMPT    84
                  GO TO 19                                                         MSLAIMPT    85
               13 IF(KT.EQ.0) GO TO 20                                             MSLAIMPT    86
                  IF(ML.GT.MT) GO TO 20                                            MSLAIMPT    87
               14 RA=REL(10)                                                       MSLAIMPT    88
                  RADOT=REL(11)                                                    MSLAIMPT    89
                  SI=Z(3)                                                          MSLAIMPT    90
                  SIP=ZP(3)                                                        MSLAIMPT    91
                  SIQ=Z(4)                                                         MSLAIMPT    92
                  SIQP=ZP(4)                                                       MSLAIMPT    93
                  ML=MT                                                            MSLAIMPT    94
                  GO TO 19                                                         MSLAIMPT    95
               20 RA=RELF(7,JTM)                                                   MSLAIMPT    96
                  RADOT=RELF(9,JTM)                                                MSLAIMPT    97
                  SI=ZF(1,JTM)                                                     MSLAIMPT    98
                  SIP=ZFP(1,JTM)                                                   MSLAIMPT    99
                  SIQ=ZF(2,JTM)                                                    MSLAIMPT   100
                  SIQP=ZFP(2,JTM)                                                  MSLAIMPT   101
               19 RETURN                                                           MSLAIMPT   102
                  END                                                              MSLAIMPT   103
```

Table 6-2. Missile FOV



1. FLARES IN THE FOV

IF, $\left|\psi_F(K) - \psi_A\right| \leq \frac{FOV}{2}$

AND

$\left|\psi_F'(K) - \psi_A'\right| \leq \frac{FOV}{2}$

THEN, $N_F(J) = K$

$N_F(J) \triangleq$ ARRAY STORING THE FLARES WHICH ARE IN THE FOV

LT = TOTAL NO. OF FLARES IN THE FOV

2. TARGET IN THE FOV

IF, $\left|\psi - \psi_A\right| \leq \frac{FOV}{2}$

AND

$\left|\psi - \psi_A'\right| \leq \frac{FOV}{2}$

THEN, KT = 1 OTHERWISE, KT = 0

The aimpoint type can be based on

1. geometric centroid
2. irradiance centroid
3. maximum irradiance

of IR sources within the FOV above the minimum detectable irradiance level. In general, con-scan, FM signal processing missiles are max irradiance trackers and spin-scan AM signal processing missiles are irradiance centroid trackers.

The aimpoint determines the angles ψ_A, ψ_A', angle rates, $\dot{\psi}_A$, $\dot{\psi}_A'$ and the range rate $\dot{r}_A$ which represent the direction, direction rates and the range rate from the missile to an apparent target within the FOV. The equations used to calculate ψ_A, ψ_A', $\dot{\psi}_A$, $\dot{\psi}_A'$ and $\dot{r}_A$ for each aimpoint condition are shown in Table 6-3.

These aimpoint variables are fed back into the dynamics portion of the program to determine gyro position and rate and ultimately to determine the missile guidance commands.

Table 6-3. Missile aimpoint

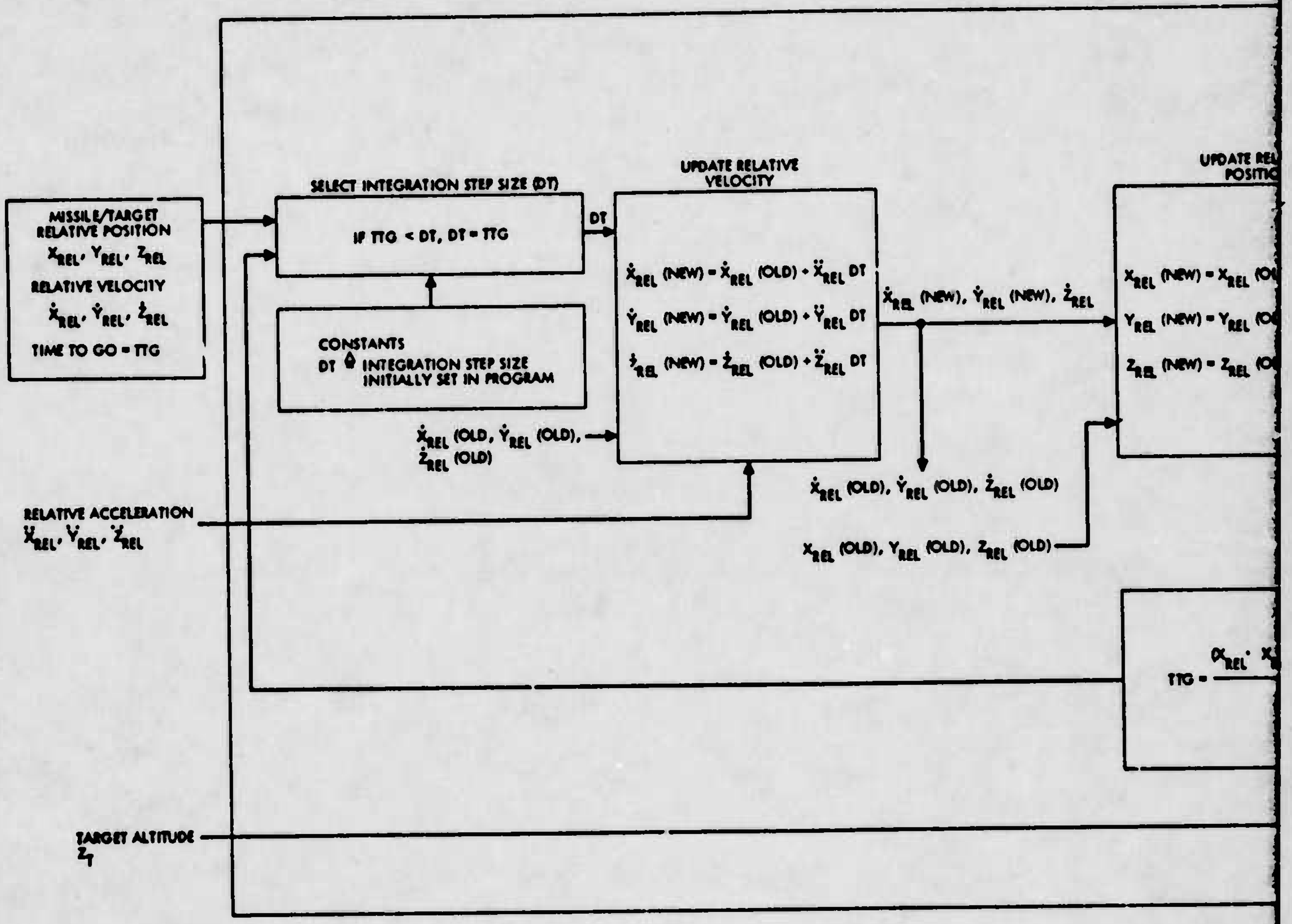
Geometric Centroid	Irradiance Centroid	Maximum Irradiance
$r_A = \dfrac{\sum_{J=1}^{LT} r_F(N_F(J)) + KT * r}{LT + KT}$	$r_A = \dfrac{\sum_{J=1}^{LT} H_F(N_F(J)) * r_F(N_F(J)) + H_T * KT * r}{H_F(N_F(J)) + KT * H_T}$	$H_F(N_F(J1)) = \max_J \{H_F(N_F(J))\ J = 1, LT\}$ If, $H_T(J1) \geq H_T$ Then, $r_A = r_F(N_F(J1))$ $\dot{r}_A = \dot{r}_F(N_F(J1))$ $\psi_A = \psi_F(N_F(J1))$ $\psi'_A = \psi'_F(N_F(J1))$ $\dot{\psi}_A = \dot{\psi}_F(N_F(J1))$ $\dot{\psi}'_A = \dot{\psi}'_F(N_F(J1))$ Otherwise, $r_A = r$ $r_A = \dot{r}$ $\psi_A = \psi$ $\psi'_A = \psi'$ $\dot{\psi}_A = \dot{\psi}$ $\dot{\psi}'_A = \dot{\psi}'$
$\dot{r}_A = \dfrac{\sum_{J=1}^{LT} \dot{r}_F(N_F(J)) + KT * \dot{r}}{LT + KT}$	$\dot{r}_A = \dfrac{\sum_{J=1}^{LT} H_F(N_F(J)) * r_f(N_F(J)) + H_T * KT * \dot{r}}{H_F(N_F(J)) + KT * H_T}$	
$\psi_A = \dfrac{\sum_{J=1}^{LT} \psi_F(N_F(J)) + KT * \psi}{LT + KT}$	$\psi_A = \dfrac{\sum_{J=1}^{LT} H_F(N_F(J)) * \psi_F(N_F(J)) + H_T * KT * \psi}{H_F(N_F(J)) + KT * H_T}$	
$\psi'_A = \dfrac{\sum_{J=1}^{LT} \psi'_F(N_F(J)) + KT * \psi'}{LT + KT}$	$\psi'_A = \dfrac{\sum_{J=1}^{LT} H_F(N_F(J)) * \psi'_F(N_F(J)) + H_T * KT * \psi'}{H_F(N_F(J)) + KT * H_T}$	
$\dot{\psi}_A = \dfrac{\sum_{J=1}^{LT} \dot{\psi}(N_F(J)) + KT * \dot{\psi}}{LT + KT}$	$\dot{\psi}_A = \dfrac{\sum_{J=1}^{LT} H_F(N_F(J)) * \dot{\psi}_F(N_F(J)) + H_T * KT * \dot{\psi}}{H_F(N_F(J)) + KT * H_T}$	
$\dot{\psi}'_A = \dfrac{\sum_{J=1}^{LT} \dot{\psi}'(N_F(J)) + KT * \dot{\psi}'}{LT + KT}$	$\dot{\psi}'_A = \dfrac{\sum_{J=1}^{LT} H_F(N_F(J)) * \dot{\psi}'_F(N_F(J)) + H_T * KT * \dot{\psi}'}{H_F(N_F(J)) + KT * H_T}$	

7. CLOSEST APPROACH COMPUTATION

This subroutine is called when the missile no longer has a source within the seeker FOV. The missile and target trajectories are projected foreward in time, assuming missile and target accelerations remain constant, at the last value, before loss of tracking.

Figure 7-1 shows a block diagram of the computation. The trajectory is projected forward until the missile passes the target (normal termination), begins to diverge, hits the ground, or exceeds the maximum missile lifetime.

The computed time to go (TTG) is the time remaining to closest approach assuming constant missile and target velocities. It is equal to the projection of the range in the relative velocity direction, divided by the magnitude of the relative velocity. Table 7-1 gives the closest approach computation subroutine.


MISSILE/TARGET RELATIVE POSITION
$X_{REL}, Y_{REL}, Z_{REL}$
RELATIVE VELOCITY
$\dot{X}_{REL}, \dot{Y}_{REL}, \dot{Z}_{REL}$
TIME TO GO = TTG
SELECT INTEGRATION STEP SIZE (DT)
IF TTG < DT, DT = TTG
CONSTANTS
DT ≙ INTEGRATION STEP SIZE INITIALLY SET IN PROGRAM
DT
UPDATE RELATIVE VELOCITY
$\dot{X}_{REL}$ (NEW) = $\dot{X}_{REL}$ (OLD) + $\ddot{X}_{REL}$ DT
$\dot{Y}_{REL}$ (NEW) = $\dot{Y}_{REL}$ (OLD) + $\ddot{Y}_{REL}$ DT
$\dot{Z}_{REL}$ (NEW) = $\dot{Z}_{REL}$ (OLD) + $\ddot{Z}_{REL}$ DT
$\dot{X}_{REL}$ (OLD, $\dot{Y}_{REL}$ (OLD), $\dot{Z}_{REL}$ (OLD)
$\dot{X}_{REL}$ (NEW), $\dot{Y}_{REL}$ (NEW), $\dot{Z}_{REL}$
$\dot{X}_{REL}$ (OLD), $\dot{Y}_{REL}$ (OLD), $\dot{Z}_{REL}$ (OLD)
X_{REL} (OLD), Y_{REL} (OLD), Z_{REL} (OLD)
RELATIVE ACCELERATION
$\ddot{X}_{REL}, \ddot{Y}_{REL}, \ddot{Z}_{REL}$
UPDATE REL POSITIO
X_{REL} (NEW) = X_{REL} (OL
Y_{REL} (NEW) = Y_{REL} (O
Z_{REL} (NEW) = Z_{REL} (O
TTG = $(X_{REL} \cdot X$
TARGET ALTITUDE
Z_T

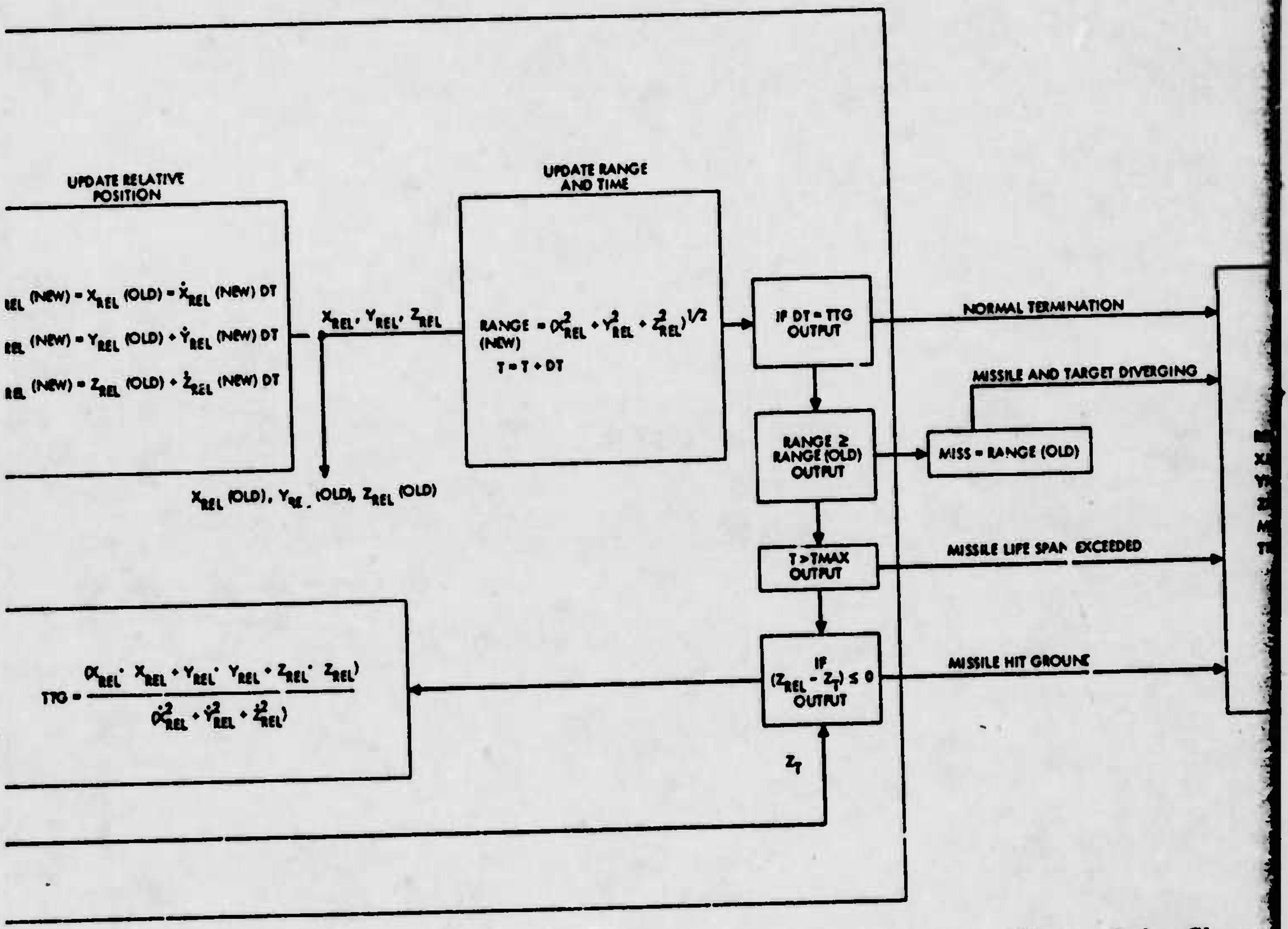

UPDATE RELATIVE POSITION
REL (NEW) = X_{REL} (OLD) = $\dot{X}_{REL}$ (NEW) DT
REL (NEW) = Y_{REL} (OLD) + $\dot{Y}_{REL}$ (NEW) DT
REL (NEW) = Z_{REL} (OLD) + $\dot{Z}_{REL}$ (NEW) DT
X_{REL}, Y_{REL}, Z_{REL}
X_{REL} (OLD), Y_{RE} (OLD), Z_{REL} (OLD)
UPDATE RANGE AND TIME
RANGE (NEW) = $(X_{REL}^2 + Y_{REL}^2 + Z_{REL}^2)^{1/2}$
T = T + DT
IF DT = TTG OUTPUT
NORMAL TERMINATION
MISSILE AND TARGET DIVERGING
RANGE ≥ RANGE (OLD) OUTPUT
MISS = RANGE (OLD)
T > TMAX OUTPUT
MISSILE LIFE SPAN EXCEEDED
IF $(Z_{REL} - Z_T) \le 0$ OUTPUT
MISSILE HIT GROUNE
Z_T
TTG = $\dfrac{(X_{REL} \cdot \dot{X}_{REL} + Y_{REL} \cdot \dot{Y}_{REL} + Z_{REL} \cdot \dot{Z}_{REL})}{(\dot{X}_{REL}^2 + \dot{Y}_{REL}^2 + \dot{Z}_{REL}^2)}$
B
X
Y
Z
M
T

Figure 7-1. Closes
compu

7

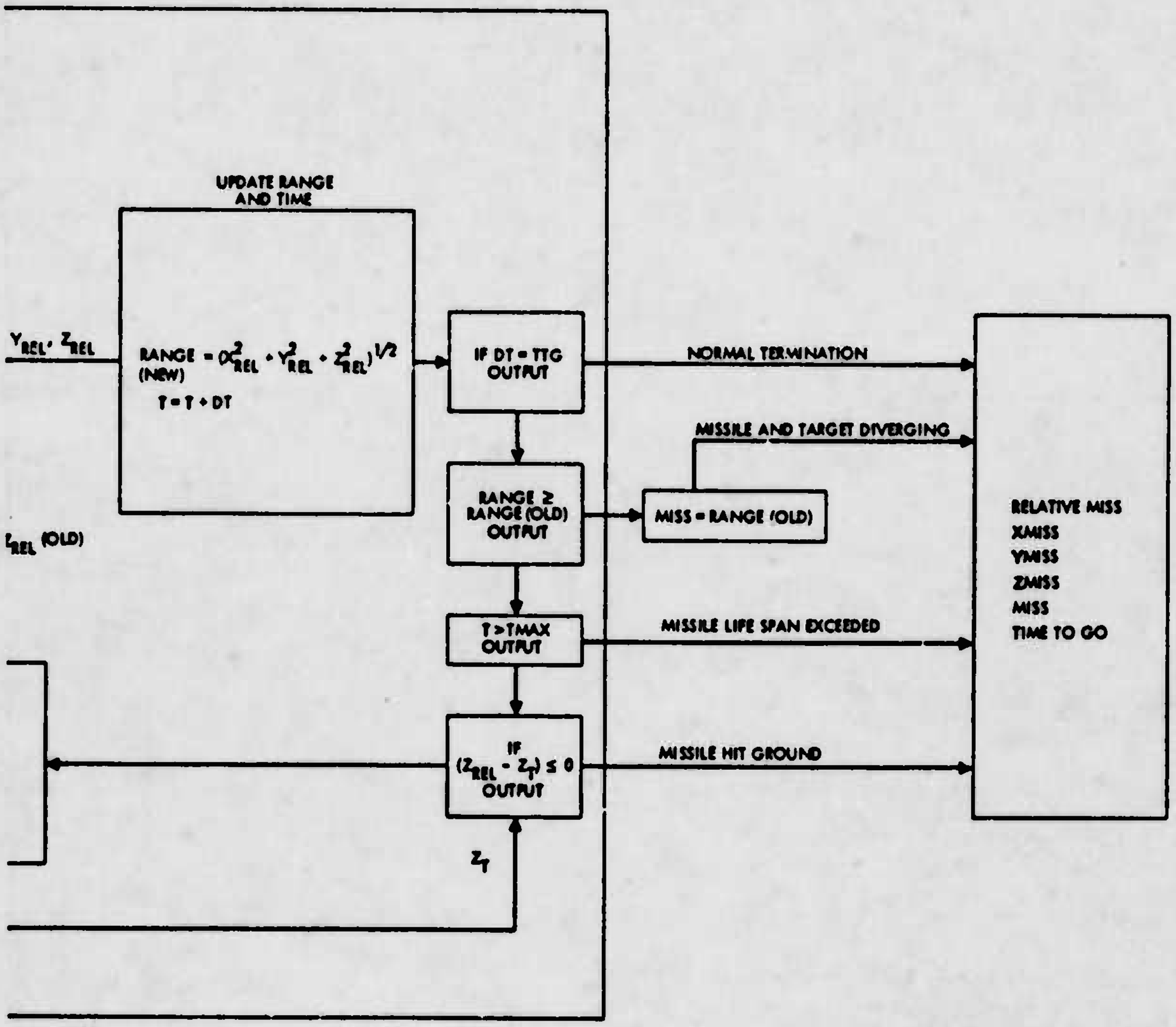


Figure 7-1. Closest approach computation

Table 7-1. Closest approach computation

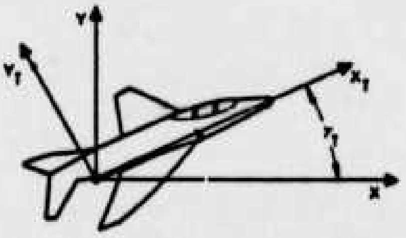
```
                                                                     FTN 4.2+P384      09/01/75  13.31.49.
SUBROUTINE CLOSAPP    74/74   OPT=1

                                                                                   MARL9       92
              SUBROUTINE CLOSAPP(REL,TTG,DELT,RMISS,XP,T,TMAX,XM,YM,ZM,ITGT(      CLOSAPPR     3
              DIMENSION REL(12),XP(18)                                             CLOSAPPR     4
              XM=REL(1)                                                            CLOSAPPR     5
              YM=REL(2)                                                            CLOSAPPR     6
              ZM=REL(3)                                                            CLOSAPPR     7
              TTGT=TTG                                                             CLOSAPPR     8
              IT=1                                                                 CLOSAPPR     9
            5 IF(TTG.GE.DELT) GO TO 1                                              CLOSAPPR    10
              DELT=TTG                                                             CLOSAPPR    11
            1 REL(4)=REL(4)+REL(7)*DELT                                            CLOSAPPR    12
              REL(5)=REL(5)+REL(8)*DELT                                            CLOSAPPR    13
              REL(6)=REL(6)+REL(9)*DELT                                            CLOSAPPR    14
              REL(1)=REL(1)+REL(4)*DELT                                            CLOSAPPR    15
              REL(2)=REL(2)+REL(5)*DELT                                            CLOSAPPR    16
              REL(3)=REL(3)+REL(6)*DELT                                            CLOSAPPR    17
              RSQR=REL(1)*REL(1)+REL(2)*REL(2)+REL(3)*REL(3)                       CLOSAPPR    18
              VRSQ=REL(4)*REL(4)+REL(5)*REL(5)+REL(6)*REL(6)                       CLOSAPPR    19
              RRDOT=REL(1)*REL(4)+REL(2)*REL(5)+REL(3)*REL(6)                      CLOSAPPR    20
              T=T+DELT                                                             CLOSAPPR    21
              CMISS=SQRT(RSQR)                                                     CLOSAPPR    22
              IF(DELT.EQ.TTG) GO TO 2                                              CLOSAPPR    23
              TTG=-RRDOT/VRSQ                                                      CLOSAPPR    24
              IF(CMISS.GT.RMISS.AND.IT.EQ.1) GO TO 4                               CLOSAPPR    25
              IF(CMISS.GT.RMISS.AND.IT.GT.1) GO TO 2                               CLOSAPPR    26
              IF(T.GT.TMAX) GO TO 7                                                CLOSAPPR    27
              RMISS=CMISS                                                          CLOSAPPR    28
              IT=IT+1                                                              CLOSAPPR    29
              IF((REL(3)-XP(3)).GT.0.) GO TO 5                                     CLOSAPPR    30
              WRITE(6,8)                                                           CLOSAPPR    31
            8 FORMAT(1X,19HMISSILE HIT GROUND)                                     CLOSAPPR    32
              GO TO 2                                                              CLOSAPPR    33
            4 WRITE(6,3)                                                           CLOSAPPR    34
            3 FORMAT(1X,29HMISSILE AND TARGET DIVERGING)                           CLOSAPPR    35
              GO TO 2                                                              CLOSAPPR    36
            7 WRITE(6,9)                                                           CLOSAPPR    37
            9 FORMAT(1X,25HMISSILE LIFE SPAN EXCEEDED)                             CLOSAPPR    38
            2 RETURN                                                               CLOSAPPR    39
              END
```

8. PROBABILITY OF HIT

It is necessary when evaluating thousands of computer runs (1) to use the probability of hit (P_H) as the only measure of effectiveness in the simulation and (2) to have a simple means of computing P_H so as to keep overall program complexity and computation time to a minimum. The approach taken here to calculate P_H utilizes the following assumptions and definitions:

1. The missile aimpoint is located at the geometric centroid of all the aircraft's tailpipes and thus the point of missile closest approach to the aircraft is relative to the tailpipe.
2. The tailpipes of the aircraft are symmetrically located about the vertical and wing axes of the aircraft.
3. The point of closest approach of the missile to the aircraft is defined to be the warhead detonation point.
4. Warhead detonation inside a volume defined by the aircraft dimensions will have a probability of hit (P_H) equal to one.
5. If the missile is a hit-to-kill missile, a detonation outside this volume will have a $P_H = 0$.
6. For proximity fused missiles, a warhead lethality zone around the aircraft volume will be assumed.
7. A warhead (proximity fused) detonation outside this iethality zone will have a $P_H = 0$. A detonation between the two zones will have P_H linearly proportional to the detonation point distance from the aircraft volume.

The missile, target, and flare simulation program provides miss distance information in inertial coordinates, therefore, it is necessary to perform a coordinate transformation to obtain the miss distance in terms of aircraft coordinates. Figure 8-1 shows the equations used to perform this transformation with the coordinates of the miss vector being (XMISS, YMISS, ZMISS) in the inertial system and (XRT, YRT, ZRT) in the aircraft system.



$$XRT = XMISS * COS\ \gamma_T - YMISS * SIN\ \gamma_T$$

$$YRT = -XMISS * SIN\ \gamma_T + YMISS * COS\ \gamma_T$$

$$ZRT = ZMISS$$

Figure 8-1. Coordinate transformation, inertial-to-aircraft coordinate

The aircraft coordinate system has the X_T and Z_T axes along the longitudinal and vertical axes of the aircraft and X_T axis along the aircraft wing. This coordinate system shown in Figure 8-2 has the tailpipe at its center and the aircraft dimensions defined relative to this point.

For proximity fused missiles, a warhead lethality zone around the aircraft volume is assumed. This zone is simply determined by adding to each aircraft dimension the warhead's effective kill radius (M_R).

If warhead detonation occurs within the aircraft volume, $P_H = 1$ is assumed; if it lies outside the warhead lethality zone, $P_H = 0$ is assumed. If warhead detonation lies between the two zones, P_H is assumed to be linearly proportional to the distance from the outer boundary of the aircraft volume to the detonation point. For the case of hit-to-kill missiles, the missile effective kill radius (M_R) is set equal to zero making the aircraft volume and warhead lethality zone coincident.

The equations and logic required to implement this calculation are as follows:

If $\quad (X_N + M_R) \le XRT \text{ and } XRT \le -(-X_B + M_R)$

Then, $\quad P_X = 0$

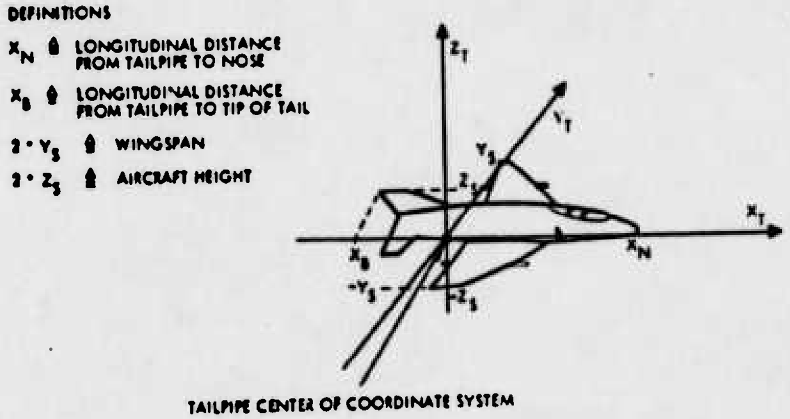

DEFINITIONS
X_N ≙ LONGITUDINAL DISTANCE FROM TAILPIPE TO NOSE
X_B ≙ LONGITUDINAL DISTANCE FROM TAILPIPE TO TIP OF TAIL
$2 \cdot Y_S$ ≙ WINGSPAN
$2 \cdot Z_S$ ≙ AIRCRAFT HEIGHT
Z_T
Y_T
X_T
Y_S
Z_S
X_B
X_N
$-Y_S$
$-Z_S$
TAILPIPE CENTER OF COORDINATE SYSTEM

Figure 8-2. Aircraft coordinate system

If $\quad -(X_B) \leq XRT \leq X_N$

Then, $\quad P_X = 1$

If $\quad XRT \geq X_N$

Then, $\quad PX = \dfrac{(X_N + M_R) - XRT}{M_R}$

Otherwise, $\quad P_X = \dfrac{(X_B + M_R) + XRT}{M_R}$

If $\quad ABS\ (YRT) \geq (Y_S + M_R)$

Then, $\quad P_Y = 0$

If $\quad ABS\ (YRT) \geq Y_S$

Then, $P_Y = 1$

Otherwise, $$P_Y = \frac{(Y_S + M_R) - \text{ABS (YRT)}}{M_R}$$

If $\text{ABS (ZRT)} \geq (Z_S + M_R)$

Then, $P_Z = 0$

If $\text{ABS (ZRT)} \leq Z_S$

Then, $P_Z = 1$

Otherwise, $$P_Z = \frac{(Z_S + M_R) - \text{ABS (ZRT)}}{M_R}$$

Finally, $$P_H = P_X * P_Y * P_Z$$

Figure 8-3 shows a block diagram of these computations. Table 8-1 gives the probability of hit subroutine.

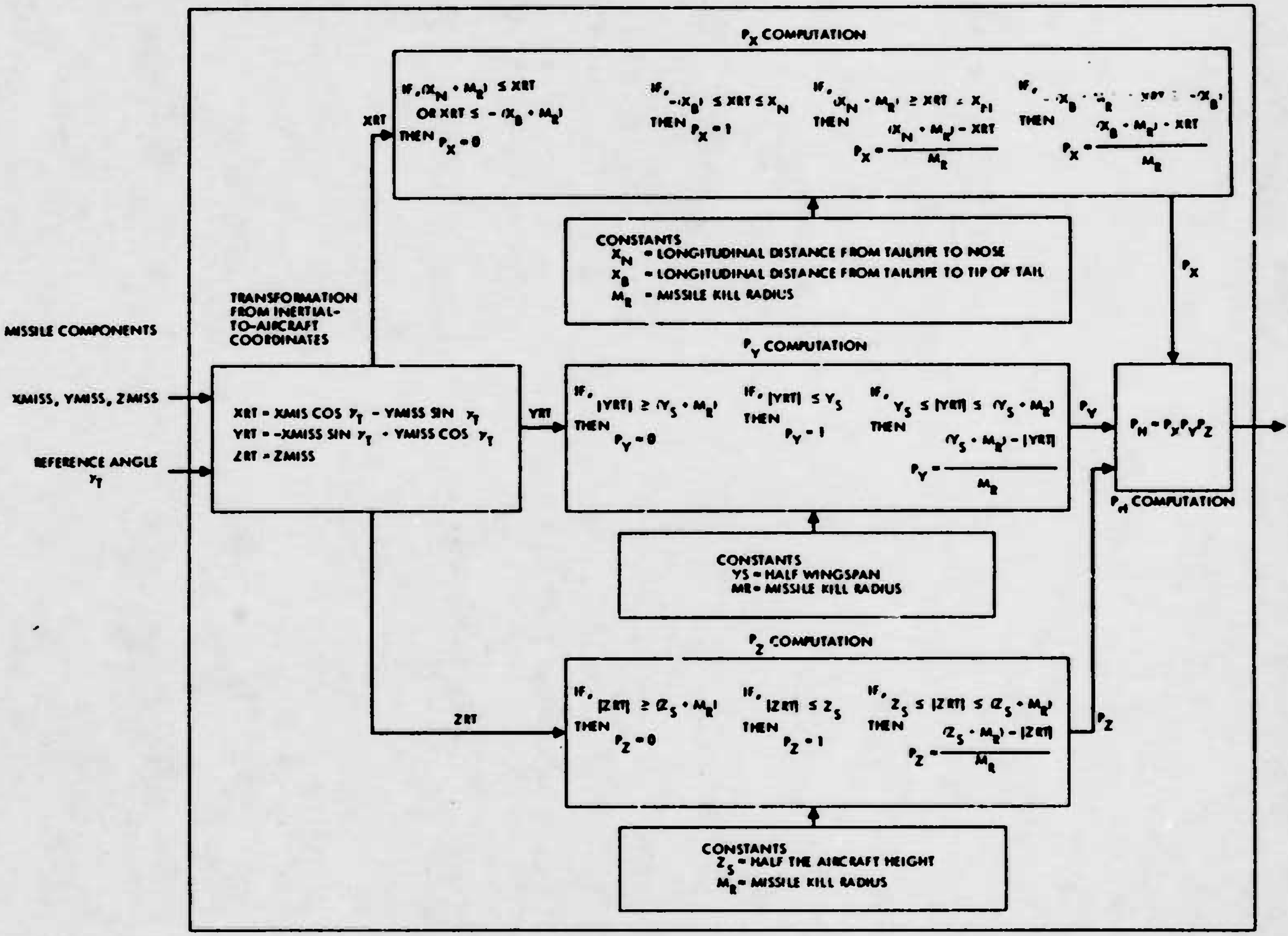
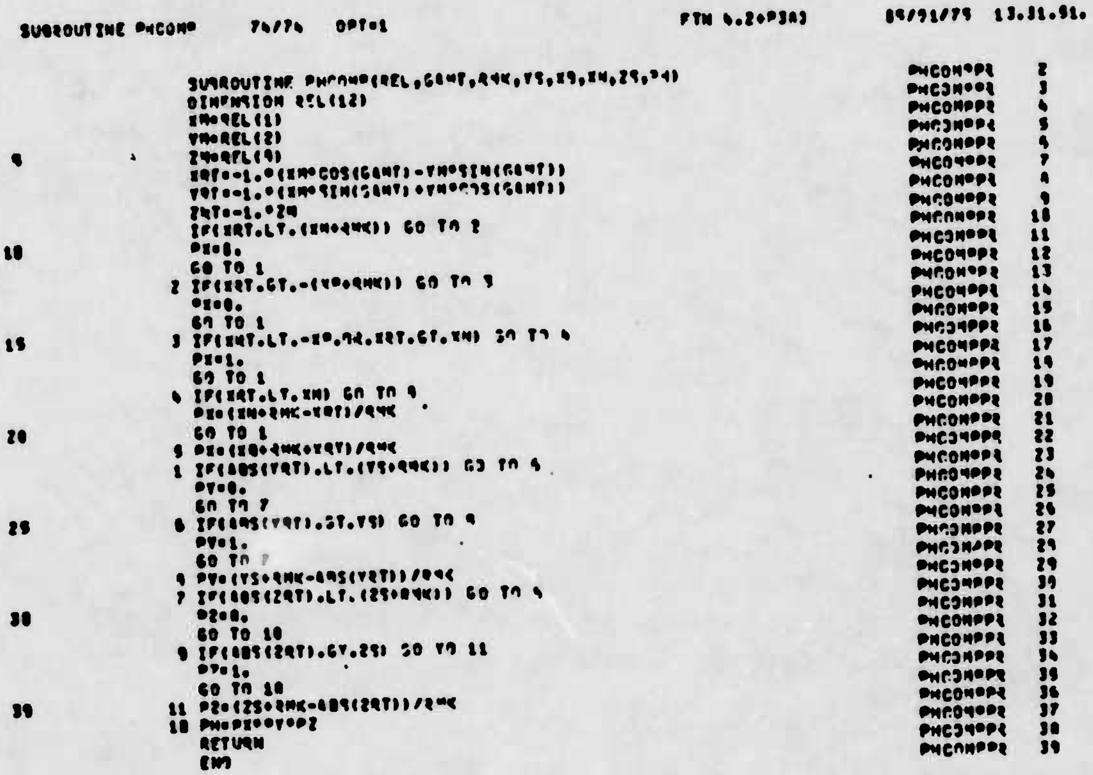

MISSILE COMPONENTS
XMISS, YMISS, ZMISS
REFERENCE ANGLE γ_T
TRANSFORMATION FROM INERTIAL-TO-AIRCRAFT COORDINATES
XRT = XMIS COS γ_T - YMISS SIN γ_T
YRT = -XMISS SIN γ_T + YMISS COS γ_T
ZRT = ZMISS
XRT
YRT
ZRT
P_X COMPUTATION
IF, $(X_N + M_R) \leq XRT$ OR $XRT \leq -(X_B + M_R)$ THEN $P_X = 0$
IF, $-(X_B) \leq XRT \leq X_N$ THEN $P_X = 1$
IF, $(X_N + M_R) \geq XRT \geq X_N$ THEN $P_X = \frac{(X_N + M_R) - XRT}{M_R}$
IF, $-(X_B + M_R) \leq XRT \leq -(X_B)$ THEN $P_X = \frac{(X_B + M_R) + XRT}{M_R}$
CONSTANTS
X_N = LONGITUDINAL DISTANCE FROM TAILPIPE TO NOSE
X_B = LONGITUDINAL DISTANCE FROM TAILPIPE TO TIP OF TAIL
M_R = MISSILE KILL RADIUS
P_Y COMPUTATION
IF, $|YRT| \geq (Y_S + M_R)$ THEN $P_Y = 0$
IF, $|YRT| \leq Y_S$ THEN $P_Y = 1$
IF, $Y_S \leq |YRT| \leq (Y_S + M_R)$ THEN $P_Y = \frac{(Y_S + M_R) - |YRT|}{M_R}$
CONSTANTS
YS = HALF WINGSPAN
MR = MISSILE KILL RADIUS
P_Z COMPUTATION
IF, $|ZRT| \geq (Z_S + M_R)$ THEN $P_Z = 0$
IF, $|ZRT| \leq Z_S$ THEN $P_Z = 1$
IF, $Z_S \leq |ZRT| \leq (Z_S + M_R)$ THEN $P_Z = \frac{(Z_S + M_R) - |ZRT|}{M_R}$
CONSTANTS
Z_S = HALF THE AIRCRAFT HEIGHT
M_R = MISSILE KILL RADIUS
P_X
P_Y
P_Z
$P_H = P_X P_Y P_Z$
P_H COMPUTATION
P_H

Figure 8-3. Probability of hit computation

]

Table 8-1. Probability of hit subroutine



```
SUBROUTINE PHCOMP     74/74   OPT=1                         FTN 4.2+P380        05/21/75  13.31.51.

                 SUBROUTINE PHCOMP(REL,GAMT,RMK,YS,XP,XN,ZS,PH)
                 DIMENSION REL(12)
                 XM=REL(1)
                 YM=REL(2)
                 ZM=REL(3)
                 XRT=-1.*(XM*COS(GAMT)-YM*SIN(GAMT))
                 YRT=-1.*(XM*SIN(GAMT)+YM*COS(GAMT))
                 ZRT=-1.*ZM
                 IF(XRT.LT.(XN+RMK)) GO TO 2
                 PX=0.
                 GO TO 1
               2 IF(XRT.GT.-(XP+RMK)) GO TO 3
                 PX=0.
                 GO TO 1
               3 IF(XRT.LT.-XP.OR.XRT.GT.XN) GO TO 4
                 PX=1.
                 GO TO 1
               4 IF(XRT.LT.XN) GO TO 5
                 PX=(XN+RMK-XRT)/RMK
                 GO TO 1
               5 PX=(XP+RMK+XRT)/RMK
               1 IF(ABS(YRT).LT.(YS+RMK)) GO TO 6
                 PY=0.
                 GO TO 7
               6 IF(ABS(YRT).GT.YS) GO TO 8
                 PY=1.
                 GO TO 7
               8 PY=(YS+RMK-ABS(YRT))/RMK
               7 IF(ABS(ZRT).LT.(ZS+RMK)) GO TO 9
                 PZ=0.
                 GO TO 10
               9 IF(ABS(ZRT).GT.ZS) GO TO 11
                 PZ=1.
                 GO TO 10
              11 PZ=(ZS+RMK-ABS(ZRT))/RMK
              10 PH=PX*PY*PZ
                 RETURN
                 END
```

9. SPECTRAL INTEGRATOR

In order to utilize the I/R target signature generated by ASDIR II[*] (or any other computer program which can generate apparent spectral radiant intensity $J_\lambda T_\lambda$) it is necessary to integrate $J_\lambda T_\lambda$ over the optical waveband of the missile simulated in the M/T/CM program. This integration is accomplished by use of an auxiliary routine SPKINT, which can integrate over any desired spectral region of the ASDIR-II output (maximum of 50).

Two options are available in SPKINT which can be selected at run time and extend the usefulness of this routine. These include:

(1) An atmospheric transmission table can be read in at run time and used in the integration

(2) A spectral filter can be read in and applied to the integration.

Using the optional atmospheric table and/or filter table, the integrated $J_\lambda T_\lambda$ can be determined as a function of range or, if these tables are omitted, the values of $J_\lambda T_\lambda$ as a function of range from the ASDIR-II output are used. Figure 9-1 is a block diagram of the SPKINT program and Table 9-1 is a program listing.

[*] Stone, C.W., Capt. USAF and Tate, Stanley, Planning ASDIR-II (Vols I, II, III) Deputy for Development, Aeronautical Systems Division, Wright Patterson Air Force Base, Ohio, ASD/XR-TR-75-1, January 1975.

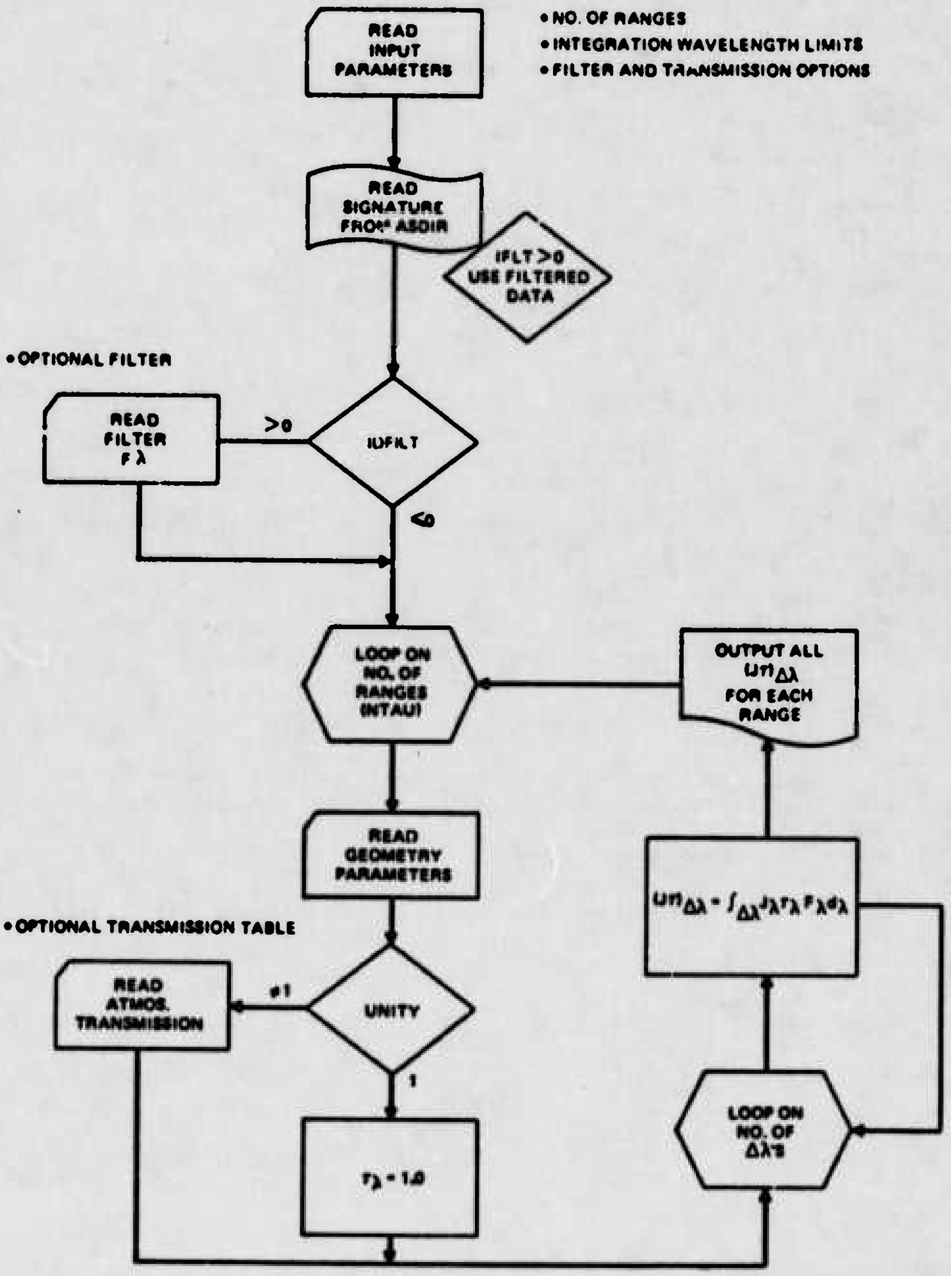

READ INPUT PARAMETERS
• NO. OF RANGES
• INTEGRATION WAVELENGTH LIMITS
• FILTER AND TRANSMISSION OPTIONS
READ SIGNATURE FROM ASDIR
IFLT > 0 USE FILTERED DATA
• OPTIONAL FILTER
READ FILTER Fλ
> 0
IUFILT
≤0
LOOP ON NO. OF RANGES (NTAU)
OUTPUT ALL (J?)Δλ FOR EACH RANGE
READ GEOMETRY PARAMETERS
• OPTIONAL TRANSMISSION TABLE
READ ATMOS. TRANSMISSION
≠1
UNITY
1
$\tau_\lambda = 1.0$
$(J\tau)_{\Delta\lambda} = \int_{\Delta\lambda} J_\lambda \tau_\lambda F_\lambda d_\lambda$
LOOP ON NO. OF Δλ'S

Figure 9-1. SPKINT flow diagram

Table 9-1. SPKINT program listing

```
      COMMON SFSM(50), SFTS(50), TAIS(50), WA(670), TRAN(670), ATMID(3),     0010
     *       TWT(670), TX(300), WLA(50), WLB(50), TEF(50), AIRM(50),          0020
     *       AATAN(670), TEMTAR(670), OSR(670), OSWL(100), OSRT(100),         0030
     *       STB(300), WTG(10,300), TAR(10,300), ANAM(6), LABEL(10,20),       0040
     *       NFREQ(10),RAD(10),FTAR(10,300)
C                                                                              300
C INITIALIZE DATA                                                              310
C                                                                              320
      INTEGER UNITY,SOURCE                                                    0325
      REWIND 3; REWIND 4; REWIND 7                                             330
      REWIND 10
      PI = 3.14159                                                             350
  555 READ(5,30) NSRG,IDSRT,NPRTY,MPRTY,KPLTY,KPJTAU,ITAUW,IFLT,
     *UNITY,SOURCE
      IF(NSRG.EQ.0) STOP
      OUTPUT NSRG,IDSRT,NPRTY,ITAUW,IFILT
C                                                                              360
C READ NTAU, LABEL, INPUT PARAMETERS                                           370
C                                                                              380
      IF (UNITY.EQ.1) READ(5,5) NTAU; WRITE(3,5) NTAU; GO TO 6
      IF(ITAUW.GT.0) READ(5,5) NTAU
      IF(ITAUW.LE.0) READ(3,5) NTAU
    5 FORMAT(8I5)                                                              400
    6 CONTINUE
      OUTPUT NTAU
      READ(5,10) (ANAM(I), I=1,6)                                              410
   10 FORMAT(20A4)                                                             420
      WRITE(6,20) (ANAM(I), I=1,6)                                             430
   20 FORMAT(1H1/32X,'NON-EQUISPACED SPECTRAL INTEGRATOR'//58X,'CASE'/61
     *X,6A4///)                                                                450
      IF(ITAUW.GT.0) READ(3) NFREQ(1); READ(3) (WA(I),TRAN(I), I = 1,
     *NFREQ(1)); GO TO 25
   25 CONTINUE
      NWL =NFREQ(1)
      WRITE(10,10) (ANAM(I), I=1,6)                                            530
      WRITE(10,30) KPLTY                                                       540
C                                                                              550
C READ INTEGRATION LIMITS (5 PAIRS/CARD)                                       560
C                                                                              570
      READ(5,50) (WLA(I), WLB(I), I=1,NSRG)                                    580
   50 FORMAT(10F6.0)                                                           590
C                                                                              600
C READ TARGETS (FILE 7, STORE FOR PLOTS ON FILE 10                             610
   35 READ(7,END=36) KT,(LABEL(KT,I), I = 1,20),NFREQ(KT)
       KTT = KT
      IF(KT.GT.10) OUTPUT'NO. OF TARGETS EXCEEDS 10'; STOP                     520
      IF(KT.LE.0) OUTPUT 'NO TARGETS'; STOP                                    630
      OUTPUT KT,NFREQ(KT)
      OUTPUT '=============================================='
      NTLT= NFREQ(KT)
      DO 60 I = 1,NTLT
      READ(7) WTG(KT,I), TAR(KT,I),FTAR(KT,I)
   30 FORMAT(24I3)                                                             470
      IF(IFLT.GT.0) TAR(KT,I) = FTAR(KT,I)
   60 CONTINUE
      READ(7) RAD(KT)
      IF(NPRTY.NE.0) WRITE(6,209) (LABEL(KT,I), I=1,20)
      IF(NPRTY.NE.0) WRITE(6,212)(WTG(KT,I),TAR(KT,I),I=1,NTLT)
  209 FORMAT(20A4)
```

(Table 9-1, continued)

```
  212 FORMAT(10HTGT LAMBDA  ,11X,4H TGT ,20X,'TGT LAMBDA',11X,' TGT'/(5X
     *,F7.4,4X,E12.4,10X,F7.4,4X,E12.4))
      OUTPUT '--.....................................................'
      IF(KPLTY.EQ.0) GO TO 54
      IF((KT.NE.1).AND.(SOURCE.GT.0)) GOTO 54
      WRITE(10,10) (LABEL(KT,J), J = 1,20)
      WRITE(10,55) NTLT,(WTG(KT,J),TAR(KT,J), J = 1,NTLT)
   55 FORMAT(I5/(6E12.5))                                                 740
   54 CONTINUE
      GO TO 35
   36 CONTINUE
      KT = KTT
      IF(SOURCE.GT.0)KT=1
      WRITE(4,40) NTAU, KT, NSRG, KT                                      500
   40 FORMAT(4I5)
      WRITE(4,446) (WLA(I),WLB(I), I = 1,NSRG)
  446 FORMAT(10F6.4)
C READ DETECTOR RESPONSE (OPTIONAL)                                         770
C                                                                           780
      IF(IOSRT.EQ.0) GO TO 80                                             790
      READ(5,70) (DSWL(I),DSRT(I), I=1,IDSRT)                             800
   70 FORMAT(5(F6.3,F6.4))                                                810
      WRITE(6,75) (DSWL(I),DSRT(I), I=1,IOSRT)                            820
   75 FORMAT(1H0,T47,'INPUT',26X,'INPUT'/40X,'WAVELENGTH',20X,'DETECTOR   830
     *RESPONSE'//(43X,F7.4,25X,E15.5))                                    840
   80 CONTINUE                                                            850
C                                                                           860
C MAIN  LOOP ON NTAU                                                        870
C-----------------------------                                              880
      DO 500 J=1,NTAU                                                     890
      IF(UNITY.EQ.1) READ(5,2) ATMID,HO,HS,SR,OVIR
      IF(ITAUW.GT.0) GO TO 111
      IF(UNITY.NE.1) GO TO 85                                             0894
      NWL = NTLT                                                          0896
      DO 81 I=1,NTLT                                                      0898
      TRAN(I) = 1.0                                                       0899
   81 WA(I) = WTG(1,I)                                                    0902
    2 FORMAT(3A4,4E10.3)
    . WRITE(3,90) NWL,ATMIO,HO,HS,SR,OVIR
      NM = NWL/5
      IF(NWL.GT.(NM*5)) NM=NM+1
      MA=1
      MB=5
      DO 82 MMB=1,NM
      WRITE(3,95) (WA(MC),TRAN(MC), MC= MA,MB)
      MA = MA+5
   82 MB=MB+5                                                             0904
      GO TO 111                                                           0906
   85 READ(3,90) NWL,ATMIO,HO,HS,SR,OVIR                                  910
   90 FORMAT(I5,3A4,5X,F8.2,6X,F8.2,5X,F8.0,6X,F4.0)                      920
      NM = NWL/5                                                          930
      IF(NWL.GT.(NM*5)) NM = NM+1                                         932
C                                                                           933
C READ  WAVELENGTH-TRANS. TABLE                                             936
C                                                                           940
      MA = 1                                                              950
      MB = 5
      DO 100 MMB = 1,NM                                                   970
      READ(3,95) (WA(MC),TRAN(MC), MC=MA,MB)                              980
   95 FORMAT(5(F6.3,F6.4))
```

(Table 9-1, continued)

```
      MA = MA+5
  100 MB = MB+5
  111 CONTINUE
      IF(MPNTY.NE.0) WRITE(6,110) J, (WA(I), TRAN(I), I=1,NWL)
  110 FORMAT(1H1/I3,34X,'INPUT WAVELENGTH VS. TRANSMISSION '//(4(F10.4,
     *'(U)',E14.5)))
      WRITE(10,40) KT,NWL
      IF(IDSWT.EQ.0) GO TO 130
      DO 120 I=1,NWL
  120 DSR(I) = TLU2(WA(I),DSW ,DSPT)
  130 CONTINUE
C
C LOOP ON NUMBER OF TARGETS
C
      K = J
      IF(SOURCE.GT.0)K=1
      NTLT = NFREQ(K)
      WRITE(10,10) (LABEL(K,I), I=1,20)
      OUTPUT WTG(K,1),WA(1),WTG(K,NTLT),WA(NWL)
      OUTPUT '---------------------------------------------------------'
      IF(WTG(K,1).LT.WA(1)) OUTPUT'LOW END OF TGT LESS THAN LAMBDA(1)',
     *GO TO 300
      IF(WTG(K,NTLT).GT.WA(NWL))OUTPUT 'HIGH END OF TGT GREATER THAN LAM
     *BDA(NWL)', STOP
      IF(UNITY.NE.1) GO TO 135
      DO 132 I=1,NTLT
  132 TWT(I) = TAN(K,I)
      K3=1;K4=NTLT
      GO TO 155
  135 CONTINUE
      DO 140 I=1,NTLT
      STO(I) = WTG(K,I)
  140 TX(I) = TAR(K,I)
      DO 150 I=1,NWL
  150 TWT(I) = TLU2(WA(I),STO,TX)
      W1 = WTG(K,1) ; W2 = WTG(K,NTLT)
      CALL SCRIPT(W1,W2,K3,K4,WA,NWL)
  155 CALL TRAP(K3,K4,WA,TWT,SUM)
       AJMAX = RAD(K)/SUM
      WRITE(6,170)
  170 FORMAT(///50X,'FRACTION OF TARGET PLUME IN BAND'///50X,'WAVELENGTH
     * REGION',7X,'F JTG'/)
      DO 180 I=1,NSRG
      W1 = WLA(I)
      W2 = WLB(I)
      CALL SCRIPT(W1,W2,KA,KB,WA,NWL)
      CALL TRAP(KA,KB,WA,TWT,SUMT)
      SFTS(I) = SUMT/SUM
      WRITE(6,175)WA(KA),WA(KB),SFTS(I)
  175 FORMAT(50X,F6.3,'-TO-',F6.3,4X,E12.5)
  180 CONTINUE
      DO 190 I=1,NWL
      AJMAX = 1.
  190 TEMTAR(I) = TWT(I)*AJMAX
      DO 200 I=1,NSRG
      W1 = WLA(I); W2 = WLB(I)
      CALL SCRIPT(W1,W2,KA,KB,WA,NWL)
      CALLTRAP(KA,KB,WA,TEMTAR,SUMF)
      SFSM(I) =SUMF
  200 IF(SFSM(I).LE.0) SFSM(I) = 1.
```

(Table 9-1, continued)

```
      DO 210 I=1,NWL                                                    1430
      TEMTAR(I) = TEMTAR(I) * TRAN(I)                                   1440
  210 IF(IDSRT.GT.0) TEMTAR(I) = TEMTAR(I)*D5H(I)                       1450
      WRITE(6,219)
  219 FORMAT(1X)
      WRITE(6,220) ATMID,HO,HS,SR,OVIR                                  1460
  220 FORMAT(22X,3A4,7X,'HO = ',F8.2,' M',5X,'HS = ',F8.2,' M',5X,'SR = 1470
     *',F8.0,' M',5X,'VH = ',F4.0,' KM'//)                              1480
      WRITE(6,230) RAD(K),WTG(K,1),WTG(K,NTLT),(LABEL(K,I),I=1,20),AJMAX 1500
  230 FORMAT(15X,'RAD = ',E12.4,' IN THE WAVELENGTH REGION',F8.4,' TO', 1510
     *F8.4,' MICRONS'//18X,'TARGET TYPE IS ',20A4//18X,'JSCAL = ',E12.4/ 1520
     *//)                                                               1530
      IF(SR.EQ.0.) WRITE(6,235); GO TO 244
  235 FORMAT(/12X,'WAVELENGTH REGION',10X,'J TAU',10X,'TAU EFF',10X,'TAU 1550
     * (TOTAL',9X/16X,'(MICRONS'//)
      WRITE(6,240)                                                      1540
  240 FORMAT(/12X,'WAVELENGTH REGION',10X,'J TAU',10X,'TAU EFF',10X,'TAU 1550
     * (TOTAL)',9X,'IRRADIANCE'/16X,9H(MICRONS)//)                      1560
  244 WRITE(10,245) (WA(I),TEMTAR(I), I = 1,NWL)
  245 FORMAT(5E14.6)                                                    1590
  250 CONTINUF                                                          1600
      DO 260 I=1,NSRG                                                   1610
      W1= WLA(I); W2=WLB(I)                                             1620
      CALL SCRIPT(W1,W2,KA,KB,WA,NWL)                                   1630
      CALL TRAP(KA,KB,WA,TEMTAR,SUM)
      AATAR(I) = SUM                                                    1650
      TEF(I) = SUM/SFSM(I)                                              1660
      TAIB(I) = TEF(I) * SFTS(I)                                        1670
      RS = SR*100.                                                      1680
      IF(RS.EQ.0)WRITE(6,256)WA(KA),WA(KB),AATAR(I),TEF(I),
     *TAIB(I);GO TO 260
  256 FORMAT(12X,F6.3,'-TO-',F6.3,7X,E12.5,7X,F9.7,10X,F9.7)
      AIRR(J) = AATAR(I)/RS/RS                                          1690
      WRITE(6,255)WA(KA),WA(KB),AATAR(I),TEF(I),TAIB(I),AIRR(J)
  255 FORMAT(12X,F6.3,'-TO-',F6.3,7X,E12.5,7X,F9.7,10X,F9.7,7X,E12.8)   1710
  260 CONTINUE                                                          1720
      IF(KPJTAJ.EQ.1) WRITE(6,265) (WA(I),TEMTAR(I),I=1,NWL)            1730
  265 FORMAT(1H1,42X,18HLAMBDA VS. J TAU   //(6E18.8))                  1740
  300 CONTINUE
      WRITE(6,350)                                                      1760
  350 FORMAT(1H1)                                                       1770
  800 CONTINUE                                                          1780
      GO TO 555
      END                                                               1790
```

Table 9-1 (concluded)

```
      FUNCTION TLU2(A,X,F)
      DIMENSION X(1),F(1)
      IF(A.LT.X(1)) TLU2=F(1);RETURN
      DO 1 I=1,50000
      IF(X(I).GT.X(I+1)) TLU2=F(I);RETURN
      IF(A.GE.X(I).AND.A.LE.X(I+1)) GO TO 2
    1 CONTINUE
    2 V=(A-X(I))/(X(I+1)-X(I))
      TLU2=F(I)+V*(F(I+1)-F(I))
      RETURN
      END
```

```
      SUBRAUTINE SCRIPT(W1,W2,L1,L2,WAVE,NWL)
      DIMENSION WAVE(1)
      DO 5 I= 1,NWL
      IF(WAVE(I).GT.W1) GO TO 10
 5    CONTINUE
 10   L1 = I - 1
      IF(L1.LT.1) L1 = 1
      DO 20 I=1,NWL
      IF(WAVE(I).GT.W2) GO TO 30
 20   CONTINUE
 30   L2 = I
      IF(L2.GT.NWL) L2 = NWL
      L2  = L2 - 1
      RETURN
      END
```

```
      SUBRAUTINE TRAP(L1,L2,X,Y,SUM)
      DIMENSION X(1), Y(1)
      L2 = L2-1
      SUM = 0.
      DO 10 I=L1,L2
 10   SUM = SUM + 0.5*(Y(I+1)+ Y(I)) * (X(I+1) - X(I))
      RETURN
      END
```

10. SAMPLE RUNS

A set of runs showing the interaction of the entire methodology simulation (ASDIR II, M/T/CM, and SPKINT) was made, and sample outputs are given in this section. The engine used to calculate the IR signature was the 10,000 foot default engine of ASDIR II. Engine hot part contributions were assumed using the equivalent blackbody temperature and area of 824°K and 730 cm^2 respectively (0 degrees aspect angle). The blackbody area was varied as a function of the cosine of the aspect angle which was varied at 15 degree increments from 9 to 90 degrees. Apparent $J_\lambda \tau_\lambda$ values (1.8 to 5.5 microns) were calculated for ranges of 0.0, 0.305, 1.524, 6.096, and 15.240 kilometers. These values were then integrated, by SPKINT, over five spectral intervals to generate the apparent effective $(J\tau)_{\Delta\lambda}$ values used in the M/T/CM simulation program. The integrated values of $(J\tau)_{\Delta\lambda}$ were then entered into the M/T/CM program and a typical set of missile simulation runs using a spin-scan type missile were made for aspect angles in 15 degree increments from 8 to 90 degrees, and launch range of 5,000 feet. The results of these runs were $P_s = 0$ for all but aspect angles of 75 and 90 degrees. At these two angles, the missile was unable to maneuver to catch the target (i.e., it was launched outside of the aerodynamic launch boundary) and $P_s = 1$ in these cases.

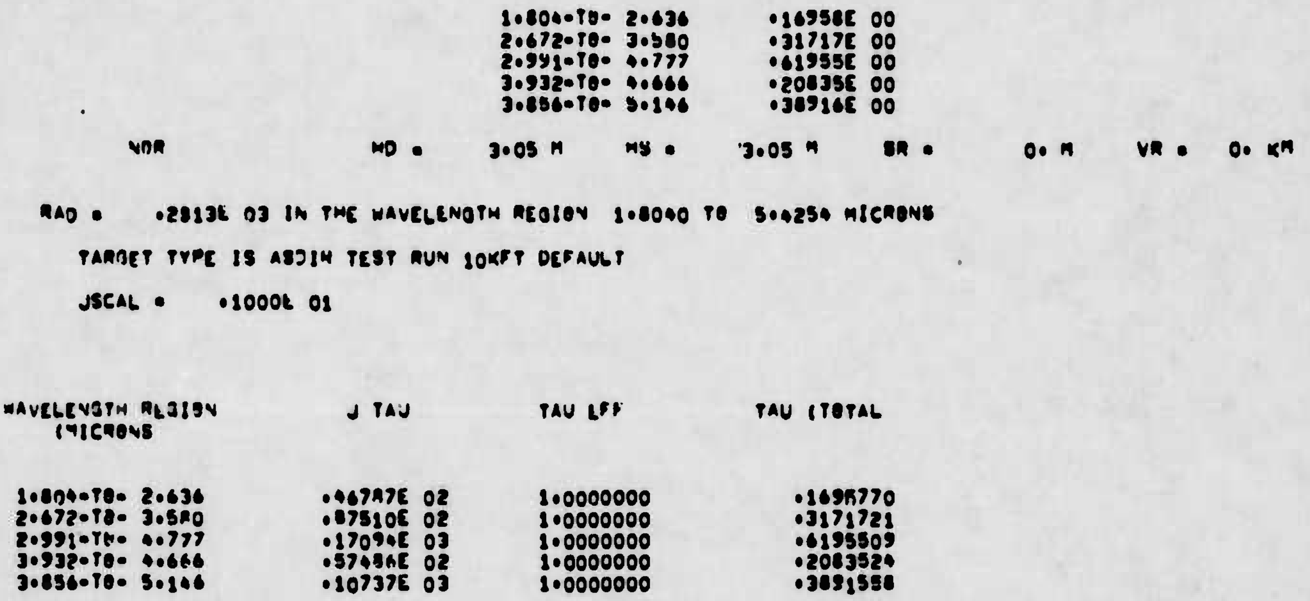
Sample outputs from these runs are shown in Tables 10-1 and 10-2 and in Figures 10-1 through 10-6.* Table 10-1 shows the ASDIR II output of $J_\lambda \tau_\lambda$ versus λ and Table 1-2 the integrated SPKINT values. Both of these cases are for 0 degrees aspect and 0 Km range. Figure 10-1 gives a plot of the spectral $J_\lambda \tau_\lambda$ for the 0 Km range case, and Figure 10-2 is a polar plot of $(J\tau)_{\Delta\lambda}$, $\Delta\lambda$ = 1.8 to 2.6μ, for three ranges. Plots of the simulated missile flight are shown in the last four figures. Missile target trajectories in the X-Z and X-Y planes are shown in Figures 10-3 and 10-4 respectively. Apparent effective intensity and effective irradiance at the missile seeker as a function of time are given in Figures 10-5 and 10-6.

*Figures 10-1 through 10-6 were generated by separate CALCOMP plotter routines which are not part of EPICS.

Table 10-1. ASDIR II output

```
***TOTAL SIGNATURE OVER THE SPECTRAL BAND 1.80 TO 5.50 MICRONS AT A RANGE OF        .000 KM
FOR AN ASPECT ANGLE OF     .0 DEGREES IN A NOR. ATMOSPHERE***

*VEHICLE ALTITUDE =   3.05 KM AND OBSERVER ALTITUDE =   3.05 KM

  BAND CENTER   BAND WIDTH  APPARENT RADIANCE   WAVENUMBER   INCREMENT   SPECTRAL RADIANCE
    MICRONS      MICRONS    WATTS/STERADIAN   (CENTER)CM-1     CM-1     WATTS/MICRON/SR

    1.8040        .0122            .3254        5543.18        37.4          26.7557
    1.8204        .0165            .4345        5493.18        50.0          26.2249
    1.8372        .0169            .4239        5443.18        50.0          25.1161
    1.8542        .0172            .4561        5393.18        50.0          26.5354
    1.8715        .0175            .4914        5343.18        50.0          28.0581
    1.8892        .0178            .5758        5293.18        50.0          32.2653
    1.9072        .0182            .5720        5243.18        50.0          31.4509
    1.9256        .0185            .6341        5193.18        50.0          34.2012
    1.9443        .0189            .6949        5143.18        50.0          36.7628
    1.9634        .0193            .7557        5093.18        50.0          39.2048
    1.9829        .0197            .8140        5043.18        50.0          41.4066
    2.0027        .0200            .8709        4993.18        50.0          43.4274
    2.0230        .0205            .9271        4943.18        50.0          45.3084
    2.0437        .0209            .9864        4893.18        50.0          47.2355
    2.0648        .0213           1.0463        4843.18        50.0          49.0849
    2.0863        .0217           1.1081        4793.18        50.0          50.9173
    2.1083        .0222           1.1726        4743.18        50.0          52.7637
    2.1308        .0227           1.2401        4693.18        50.0          54.6269
    2.1537        .0232           1.3105        4643.18        50.0          56.5084
    2.1771        .0237           1.3845        4593.18        50.0          58.4178
    2.2011        .0242           1.4620        4543.18        50.0          60.3530
    2.2256        .0247           1.5432        4493.18        50.0          62.3096
    2.2506        .0253           1.6279        4443.18        50.0          64.2760
    2.2763        .0259           1.7164        4393.18        50.0          66.2523
    2.3025        .0265           1.8084        4343.18        50.0          68.2243
    2.3293        .0271           1.9036        4293.18        50.0          70.1728
    2.3567        .0278           2.0027        4243.18        50.0          72.1144
    2.3848        .0284           2.0997        4193.18        50.0          73.8359
    2.4136        .0291           2.1901        4143.18        50.0          75.1905
    2.4431        .0299           2.2584        4093.18        50.0          75.6734
    2.4733        .0306           2.2717        4043.18        50.0          74.2726
    2.5043        .0314           2.2228        3993.18        50.0          70.8885
    2.5360        .0322           2.0920        3943.18        50.0          65.0542
    2.5686        .0330           1.6351        3893.18        50.0          49.5653
    2.6020        .0339           1.6538        3843.18        50.0          48.8522
    2.6363        .0347           2.0999        3793.18        50.0          60.4271
    2.6715        .0357            .1523        3743.18        50.0           4.2678
    2.7077        .0367            .2709        3693.18        50.0           7.3895
    2.7449        .0377            .8401        3643.18        50.0          22.3007
```

Table 10-2. SPKINT integrated output



```
                                   1.804-TO- 2.636        .16958E 00
                                   2.672-TO- 3.580        .31717E 00
                                   2.991-TO- 4.777        .61955E 00
                                   3.932-TO- 4.666        .20835E 00
                                   3.856-TO- 5.146        .38916E 00

        NOR                     HD =     3.05 M     HS =     3.05 M     SR =        0. M     VR =   0. KM

   RAD =    .2813E 03 IN THE WAVELENGTH REGION  1.8040 TO  5.4254 MICRONS

     TARGET TYPE IS ASJIM TEST RUN 10KFT DEFAULT

     JSCAL =    .1000E 01


 WAVELENGTH REGION            J TAU            TAU EFF            TAU (TOTAL
    (MICRONS

  1.804-TO- 2.636           .46787E 02        1.0000000              .1695770
  2.672-TO- 3.580           .87510E 02        1.0000000              .3171721
  2.991-TO- 4.777           .17094E 03        1.0000000              .6195509
  3.932-TO- 4.666           .57456E 02        1.0000000              .2083524
  3.856-TO- 5.146           .10737E 03        1.0000000              .3891558
```

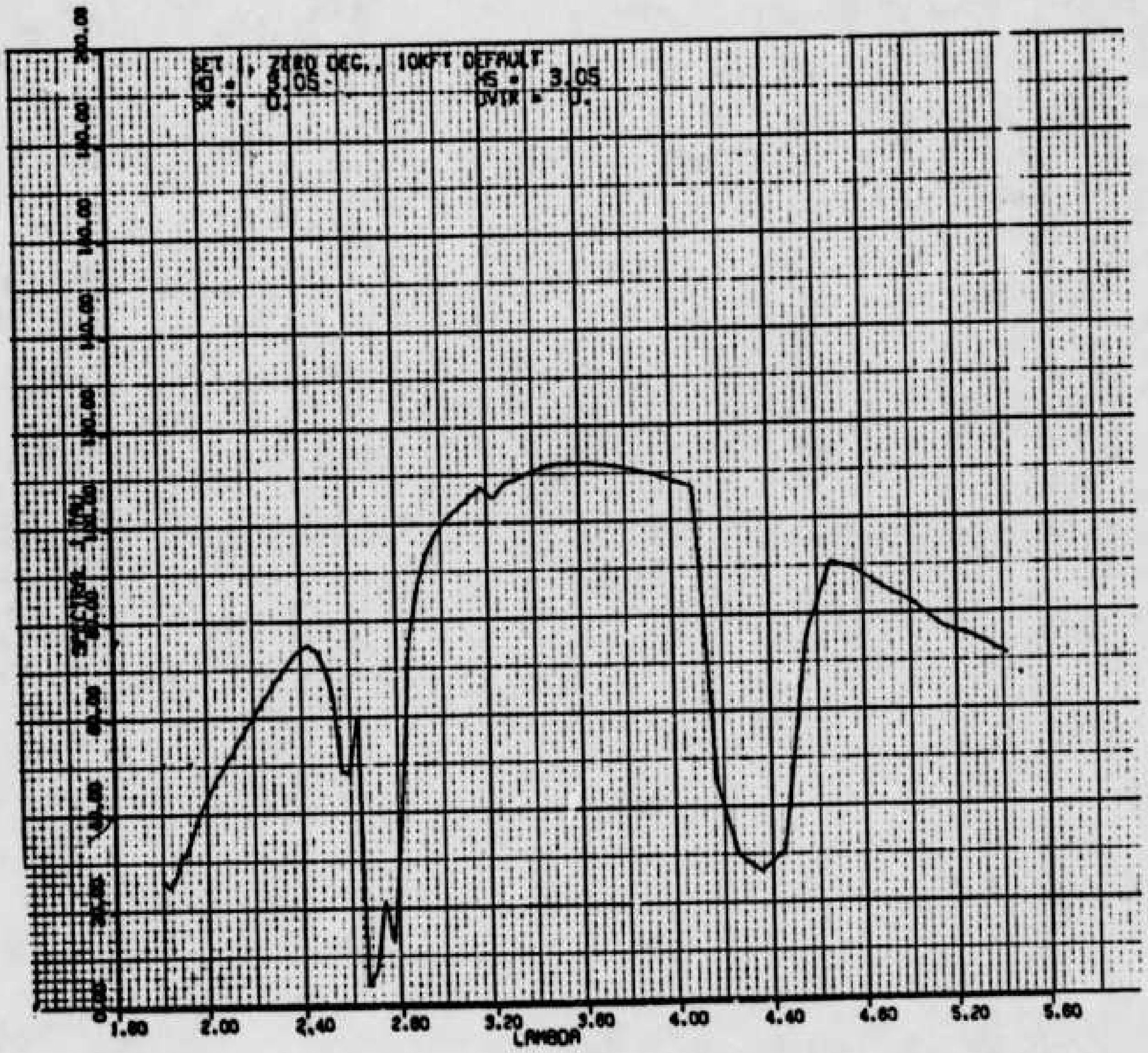


Figure 10-1. Spectral $J_{\lambda}\tau_{\lambda}$ (R = 0, aspect = 0)

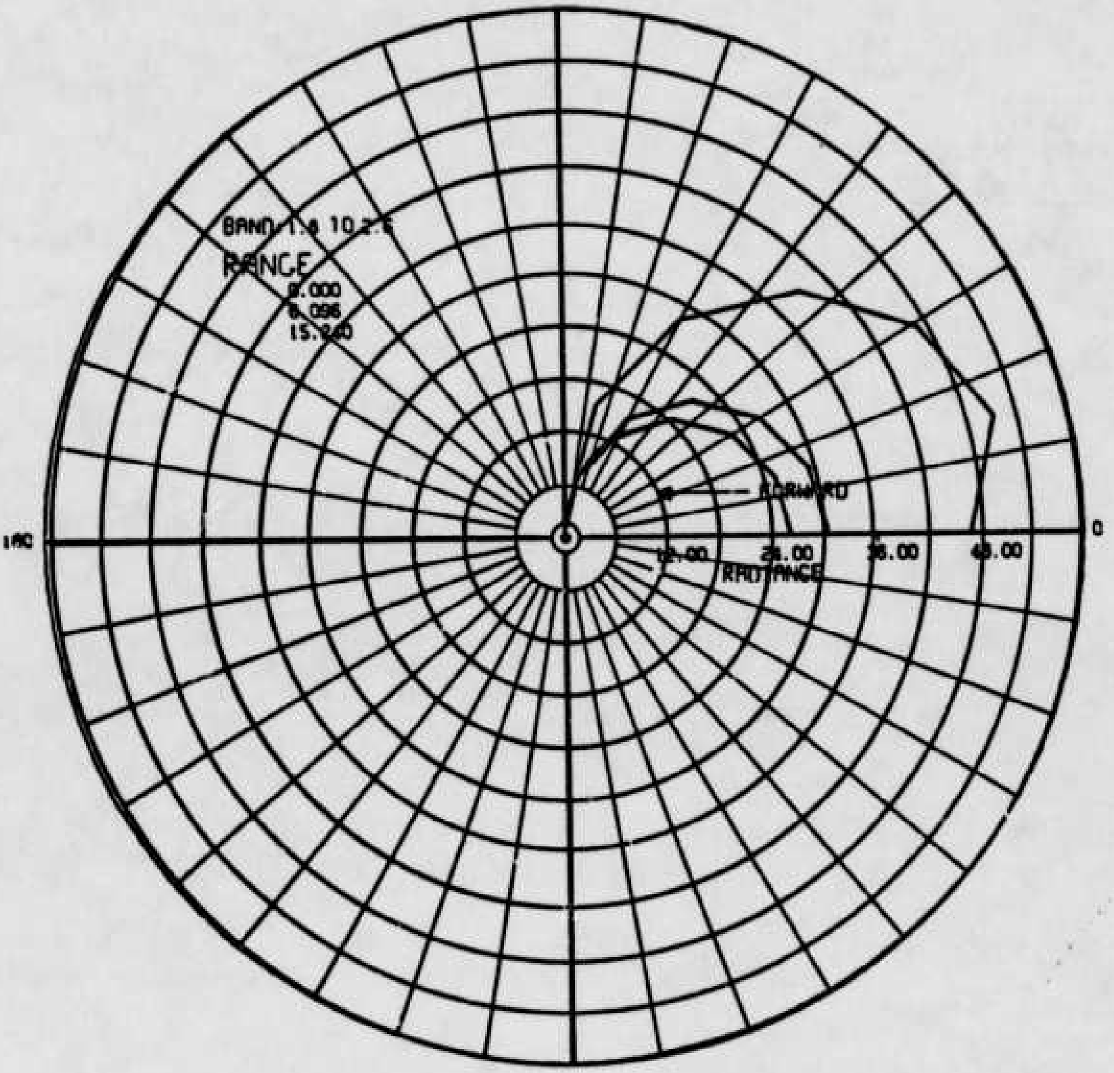


Figure 10-2. Polar plots of apparent effective radiant intensity

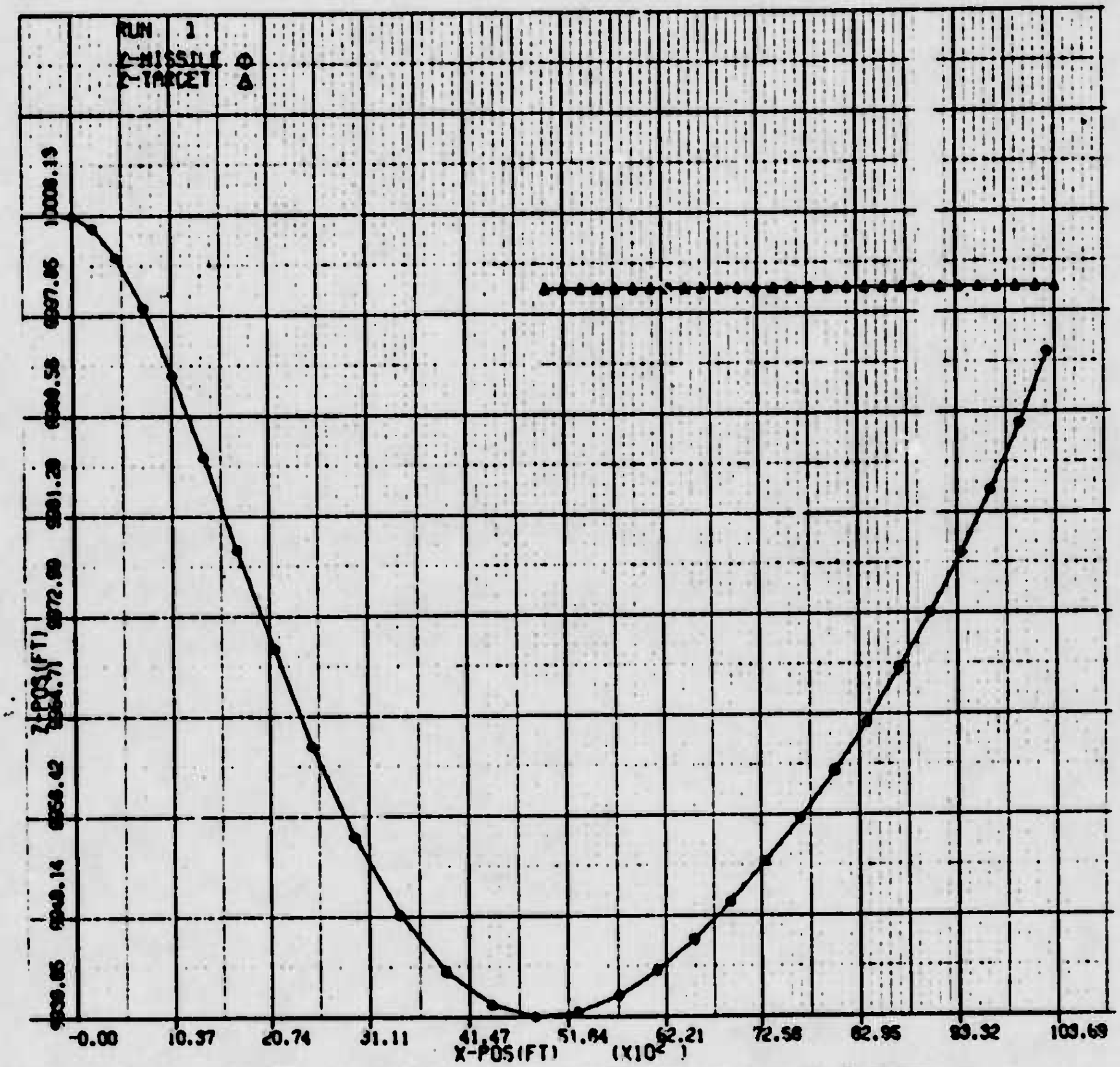


Figure 10-3. Missile - target trajectory X-Z plane

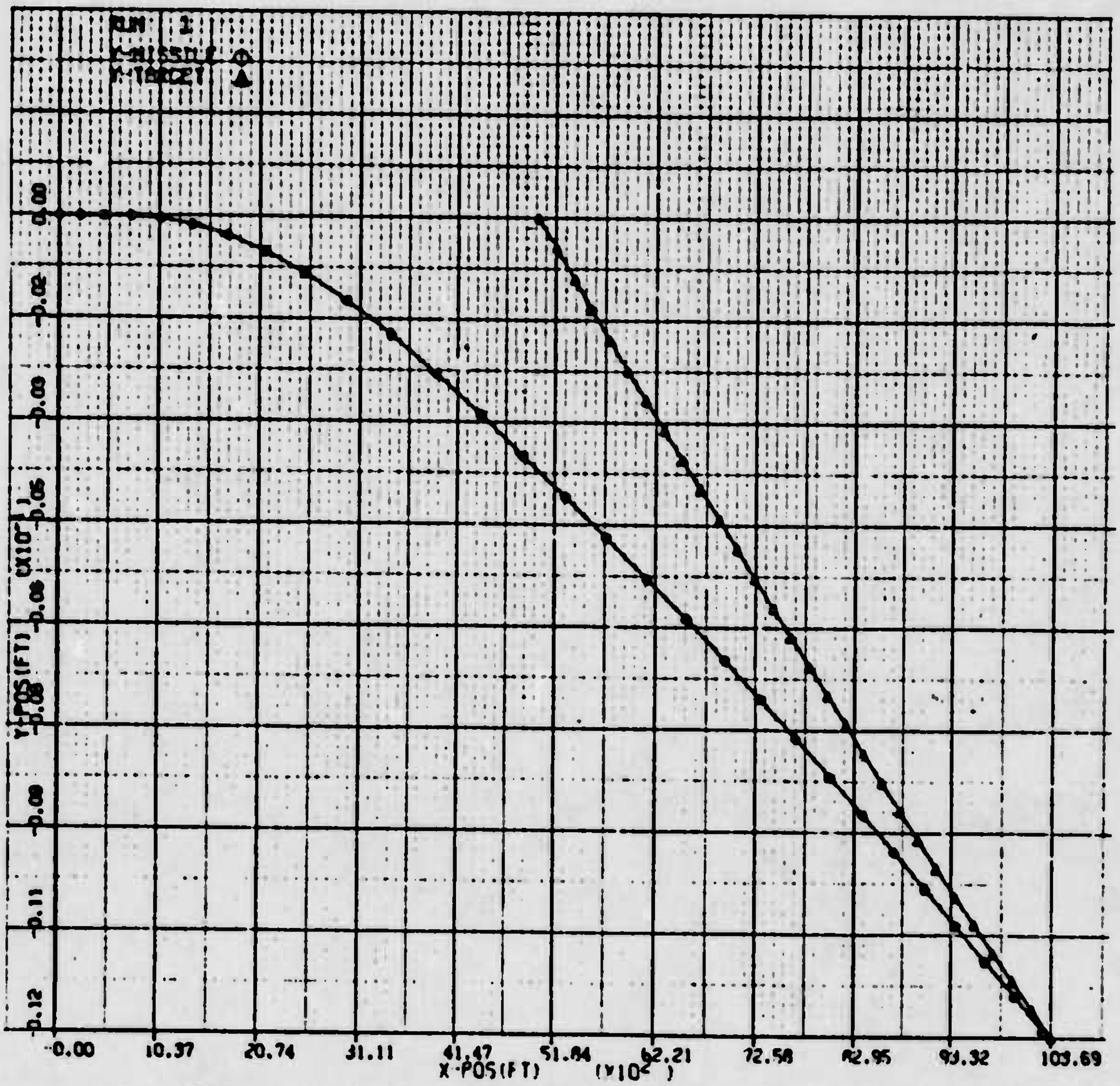


Figure 10-4. Missile-target trajectory X-Y plane

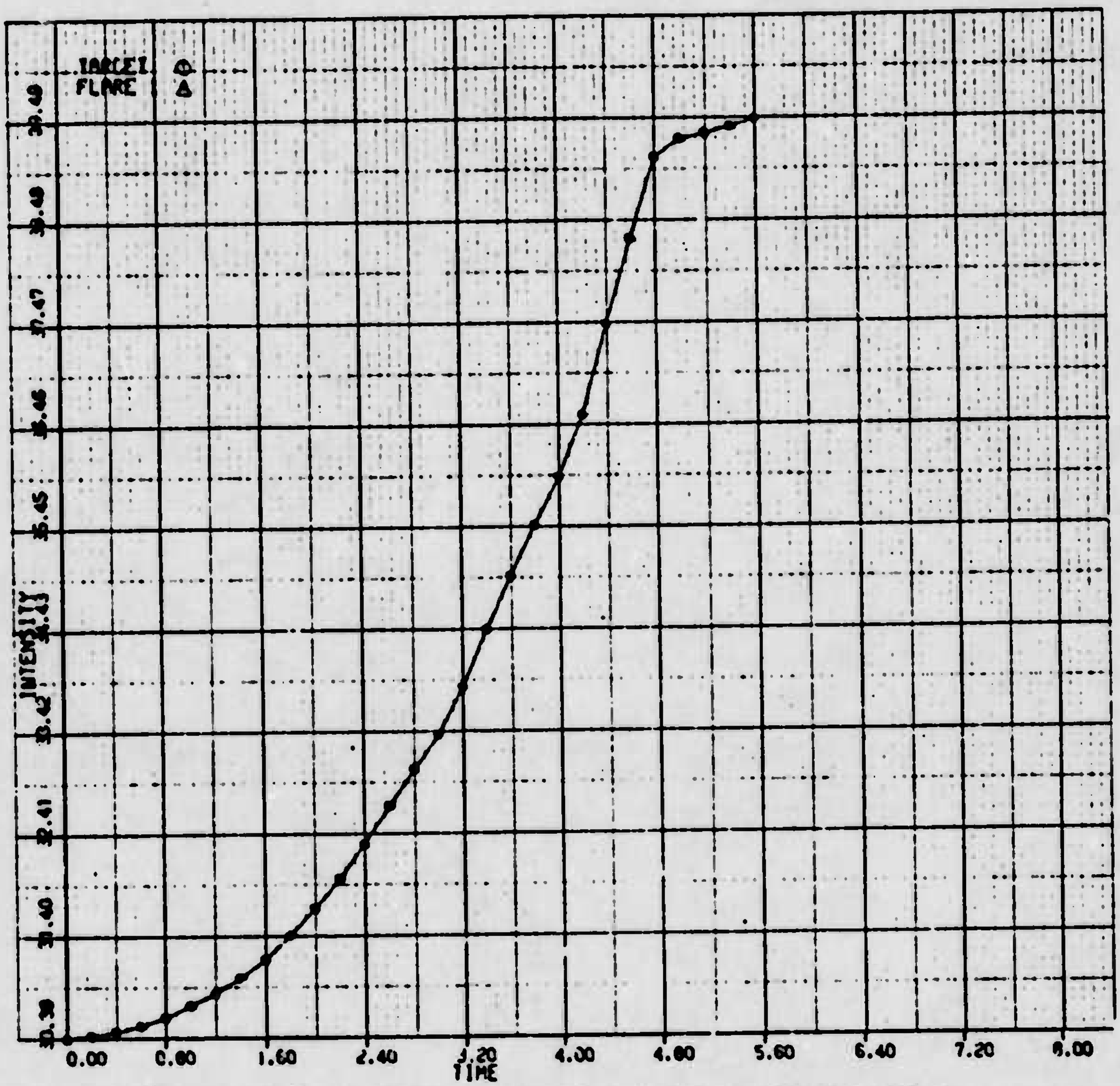


Figure 10-5. Apparent radiant intensity at missile seeker

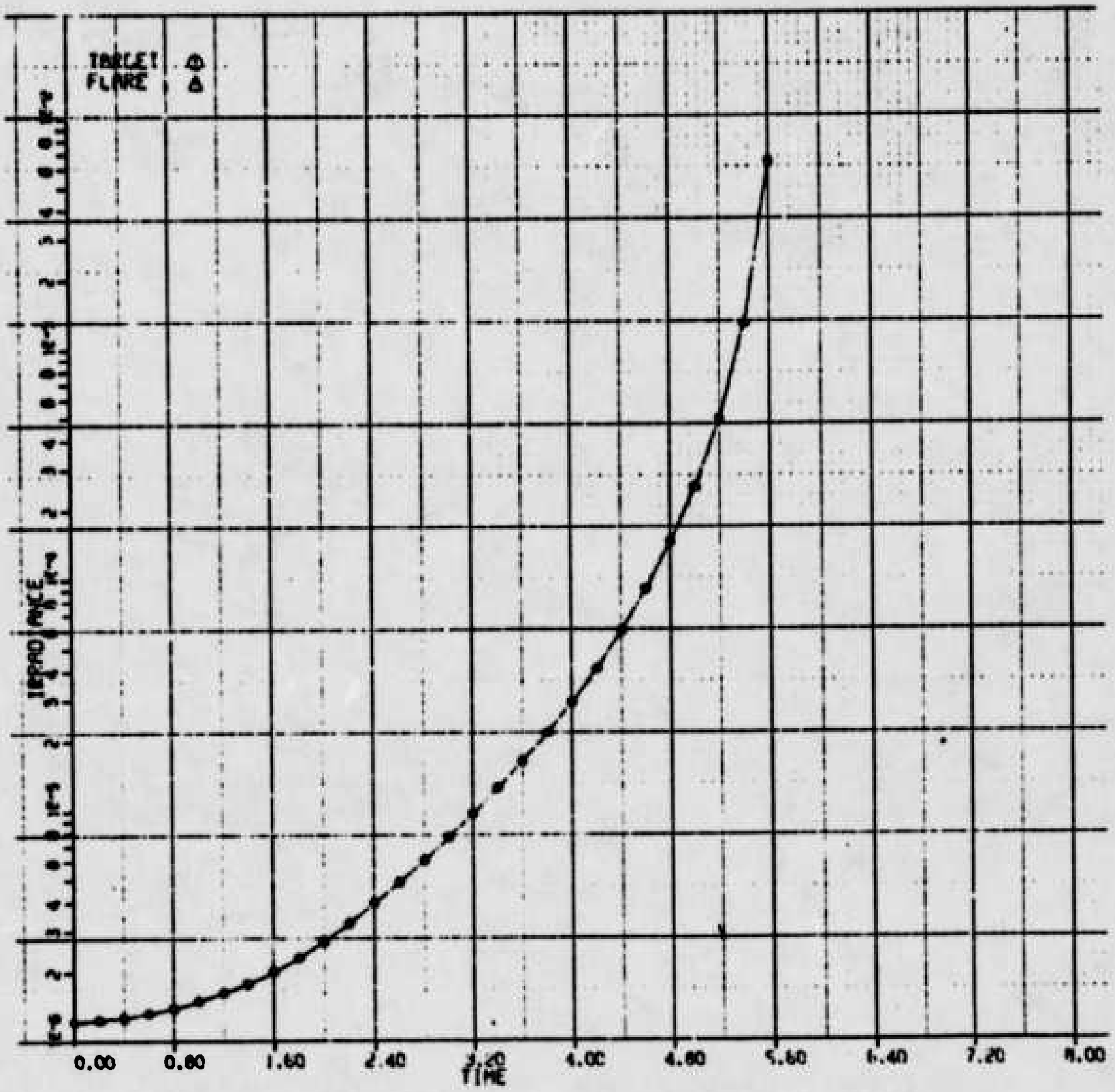


Figure 10-6. Effective irradiance at missile seeker